SCREENING OF POTATO (*Solanum tuberosum* L.) VARIETIES AGAINST SALINITY STRESS

MST. NUSRAT JAHAN

DEPARTMENT OF GENETICS AND PLANT BREEDING

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

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SCREENING OF POTATO (*Solanum tuberosum* L.) VARIETIES AGAINST SALINITY STRESS

BY

MST. NUSRAT JAHAN

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Approved by:

(Dr. Mohammad Saiful Islam)
Professor
Supervisor

(Dr. Naheed Zeba)
Professor
Co-supervisor

(Dr. Md. Abdur Rahim)
Professor and Chairman
Examination Committee

Prof. Dr. Mohammad Saiful Islam

Department of Genetics and Plant Breeding

Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh

Mobile: +88-0174-2843195

Phone: +8802-9134839

Fax: +8802-8155800

E-mail: saiful_sau@yahoo.com

CERTIFICATE

This is to certify that thesis entitled, "SCREENING OF POTATO (*Solanum tuberosum* L.) *VARIETIES AGAINST SALINITY STRESS" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of* ***MASTER OF SCIENCE IN GENETICS AND PLANT BREEDING****, embodies the result of a piece of bona fide research work carried out by MST. NUSRAT JAHAN, Registration No. 19-10034 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed during the course of this investigation has been duly acknowledged.

Dated: June, 2021

Dhaka, Bangladesh

(Dr. Mohammad Saiful Islam)

Professor

Supervisor

DEDICATED TO MY

BELOVED PARENTS

Some commonly used abbreviations

Full Word	Abbreviation	Full Word	Abbreviation
Agro ecological zone	*AEZ*	International	*Intl.*
Agriculture	*Agric.*	Journal	*J.*
Agricultural	*Agril.*	Kilogram	Kg
Agronomy	*Agron.*	Limited	Ltd.
And others	*et al.*	Least Significant Difference	*LSD*
Analysis of Variance	*ANOVA*	Membrane Stability Index	MSI
Applied	*App.*	Micro molar	Umol
Bangladesh Bareau of Statistics	BBS	Milimola	mM
Biology	*Biol.*	Murashige-Skoog	MS
Botany	*Bot.*	Negative logarithm of hydrogen ion concentration (-log [H^+])	pH
Bangladesh Agricultural Research Institute	*BARI*		
Carbon	*C*	Non -significant	Ns
Catalage	*CAT*	Parts per million	ppm
Centimeter	Cm	Percentage	**%**
Coefficient of Variance	*CV*	Polyphenoloxide	PPO
Completely Randomized Design	*CRD*	Potassium ion	K^+
		Physiology	*Physiol.*
Days After Planting	DAT	Research	*Res.*
Decisiemens per meter	*ds/m*	Science	*Sci.*
Degree celcious	°C	Sodium Chloride	*NaCl*
Duncan`s new Multiple Range Test	*DMRT*	Sher-e-Bangla Agricultural University	SAU
Dry weight	*DW*	Superoxide Dismetase	SOD
Electrical Coductivity of extract	*ECe*	Shoot Distribution Index	SDI
Environment	*Environ.*	Sodium ion	Na^+
Food and Agricultural Organization	FAO	Soil Resources and Development Institute	SRDI
Gram	G	Tuber Crops Research Centre	TCRC
Horticulture/Horticultural	*Hort.*	Variety	*var.*

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SCREENING OF POTATO (*Solanum tuberosum* L.) VARIETIES AGAINST SALINITY STRESS

BY

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ABSTRACT

This experiment was performed to screen potato varieties against salinity stress. This study was conducted in the net house of Genetics and Plant Breeding Department at Sher-e-Bangla Agricultural University from December, 2019 to March, 2020. This study was done with ten potato varieties where eight varieties were collected from Tuber Crops Research Centre (TCRC), Agricultural Research Institute (BARI), Gazipur, Bangladesh and other two varieties were collected from Sylhet which are used as local variety. The varieties were BARI Alu-29 (V_1), Pechar Chokh (V_2), BARI Alu-72 (V_3), Lal Shila (V_4), BARI Alu-53 (V_5), BARI Alu-25 (V_6), BARI Alu-28 (V_7) and BARI Alu 36 (V_8), BARI Alu-7 (V_9) and BARI Alu-73 (V_{10}). Four salinity treatments including T_1 (control), T_2 (5 dS/m), T_3 (10 dS/m), T_4 (15 dS/m) were applied to the varieties. In this experiment completely randomized design (CRD) with three replications were followed. Varieties and salinity treatment influenced singly in interaction of agromorphogenic and physiological traits of potato. Salinity treatment affected almost all traits of potato significantly except dry weight of plant and k^+ uptake. Higher plant height (55.23 cm) was found in V_5 at T_2 treatment. V_7 showed higher number of leaflets per plant under T_2 and T_3 treatment. V_8 showed higher chlorophyll content value in T_2, T_3 and T_4 treatments. V_8 also showed lower Na^+ uptake and V_3 showed higher K^+ uptake in T_4 salinity treatment. V_3 showed higher proline content with the increase of salinity treatment. From the research findings, it was reported that in case of number of tuber per plant and total weight of yield, V_3 performed better under T_2, T_3 and T_4 salinity treatments and the variety V_9 also given second highest yield under T_2 treatment. Among all the varieties V_3 performed well as a salt tolerant variety.

CHAPTER I

INTRODUCTION

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INTRODUCTION

Potato is a very popular food crop and originates from the Andes in South America. It was said that the Spanish took the potato from Latin America to Europe in the 16th century. Potato was first admired because of its flower before being appreciated for its tuber. After that potato is known as a major carbohydrate source in human and animal diets all over the world. Adaptation to long days (Hawkes, 1994; 1978, Brown, 1990) and generations of breeding led to a panel of potato varieties which is different in taste, skin colour, shape, starch content, cooking type, etc. Potato is the fast growing crop and it is allowed poor families to cultivate it on small plots and helps the people to break the circle of poverty. Hundred millions of people around the world is actually depended on potato so that they can survive. Potato (*Solanum tuberosum* L.) is noted as a future food crop by FAO to ensure food security, which is adversely affected because of salinity (Chourasia *et al*., 2021). More than 100 countries are cultivated potato under temperate, subtropical and tropical conditions. Potato ranks as the world's third most important food crop, after rice and wheat. Potato is actually an auto-tetraploid (2 = 4x = 48) and belongs to the family Solanaceae. In Solanaceae family there are 90 genera and 2800 species. Potato is a highly productive crop and as a food crop it is reported to have far greater nutritive value. It is consumed at the rate of 11.0 kg per capita per annum (FAO, 2008). It is an important vegetable but it also supplies at least 12 essential minerals other than starch (12-20%), protein (1.87%), fiber (1.80%), fats (0.1%), vitamin C and high phosphate contents with small amount of calcium and ash (Irfan, 1992). After cereals potato has been recognized as a crop of high potential that can meet future food demands.

Potato is a crop that has great yield potential per unit area and it is a key for attaining food security especially for developing countries. Potato is a crop which produces more energy and protein per unit area and unit of time than most other major food crops. It is also fat-free (Lutaladio and Castaldi, 2009). Potato is also rich in many micronutrients and vitamin C (FAO, 2008), is a good source of iron, vitamins B1, B3, B6 and minerals. It is also a source of dietary antioxidants, which may play an important role in preventing diseases which is related to ageing and a source of dietary fibre (Mulatu *et al*., 2005).

Potato is mainly consumed in Bangladesh as vegetable. Potatoes are usually used for a different of purposes like boiled, baked and fried potatoes, dehydrated mashed potatoes, canned potatoes and it is also used as starch for culinary purposes (Hoque, 1994). Otherwise, different types of food items (Singara, Samucha, Chop, Chips etc.) are also made from potato. Potato is widely cultivated in all districts of Bangladesh during winter season. November is reported as the best time for planting tuber. Meanwhile, there is a big gap between average national yield of potato in Bangladesh compared to other potato cultivated countries of the world like Netherlands, UK, France, USA and Germany. In UK, potato yield is about 48 MT/ha, which is more than two and half times higher than that of Bangladesh. In Bangladesh the local varieties exist that are giving extremely low yield. On the other hand, the local ones show lower yield than the high yielding varieties under the identical conditions and cultural practices. In recent perspective, to reduce the pressure on rice, the government has been trying to diversify food habits and encourage potato production. So, potato is leading an important food to ensure food security in Bangladesh. In Bangladesh, a number of studies to agronomic, economic and physiological aspects of potato cultivation have so far been conducted.

Soil salinity is one of the abiotic stresses that severely reduces the crop productivity in the world (Shrivastava and Kumar, 2015). Salinity continues to challenge crop under current water precarity conditions (Akrimi *et al*., 2021). Salinity has very serious and negative effect on growth and development of crop plants (Ma *et al*., 2015 and Barnawal *et al*., 2014). Due to salinity stress of the soil and application of saline water adversely influence potato cultivation in many parts of the world. It is reported that coastal or inland salinity is one of the major constraints on potato cultivation in southern and south-eastern Asia of the world. The rate of photosynthesis, respiration rate are also disturbed due to salinity and in some cases in plants causing serious yield losses (Zhang *et al*., 2005 ; Fidalgo *et al*., 2004 and Silva *et al*., 2001). In soil the higher amount of toxic salts of sodium, destroys plant roots which causing water shortages, deficiency of plant nutrients by disrupting ions uptake and transport. Na^+ and Cl^- accumulation cause ionic stress and also interfering cellular processes such as cell division. It is also caused chromosomal aberration which leads to reduce growth, development and yield of plant etc. (Munns, 2002). Due to the salinity stress drastic yield reduction in several crop plants has been seen (Zhu, 2007).

The united nation environment program reported that approximately 20% of agricultural land and 50% of crop land in the world are salt stressed. It is also reported that six of 14 billion hectares of arable land available in the world are located in these areas. And above this, about one billion hectares are affected by excess salt. In Bangladesh, coastal area is about 2.85 million hectares, offshore areas is about 833,000 hectares of the arable lands and nearly 52.8% net saline area divided in 64 upazilla of 13 districts which are affected by different degrees or levels of salinity. And it's occurred in the southern parts of the ganges tidal floodplain, in the young Meghna estuarine floodplain. In Bangladesh, coastal area constitutes 20% of the country of which 53% are affected by different levels of salinity (Karim *et al*., 2001).

Particularly in the early growth stage, potatoes are usually sensitive to salinity. Salinity is morphologically and physiologically harmful to crop plants. The growth and production of potato are reduced due to high salt contents by affecting physiological process. Salt stress shows various effect on plant such as increased respiration rate and ion toxicity, membrane instability which results from calcium and sodium displacement and also decreased efficiency of photosynthesis.

Bangladesh Export Promotion Bureau (BEPA, 2016) reported that about 70000 tons of potato has been exported to different countries in 2016. If everything goes right, it has been expected that potato is to be major export goods after garments, leather and frozen fish by 2030. Due to low yield and saline susceptibility of potato cultivars which are available in Bangladesh are not economically suitable for the cultivation in saline soil (Rahman *et al*., 2013; Uddin *et al*, 2010). Whatever, from International Potato Centre (CIP), some of the high yielding clones have been reported as salt tolerant and these varieties can be cultivated in saline belt areas. In case of large scale cultivation, it is necessary to screen or assess them against salt stress. In Bangladesh it is really unfortunate that there are very few reports available on in vitro root bioassay study protocol of salt tolerant potato varieties or genotypes.

Photosynthesis is the most important process that is affected by salinity. By narrowing the yield gap it appears that is the scope for increasing the yield of potato. In Bangladesh the southern belt is severely affected by salinity. During rabi season, most of the saline areas remain fallow. Through the expansion of potato cultivation in these areas, maximum of the food crisis may be mitigated. So, suitable varieties of potato are very important for these areas. Considering the importance and constrains to cultivate potato in saline affected areas or coastal areas of Bangladesh, an investigation was conducted with the following objectives:

1. To find out the salinity stress tolerant varieties of potato
2. To evaluate the growth and yield performance of potato varieties under different salinity level.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The potato is cultivated widely in Bangladesh. Potato is a very important vegetable crop which is specially valued for its tuber. Nowadays researcher has given much more attention for the improvement of potato in different aspects of its production under various adverse climatic conditions and salinity is one of them. However, some of the important and informative works regarding salinity effect in interaction with potato plant with related examples are explained in this chapter.

2.1 Salinity

Salinity is defined as the amount of salt dissolved in a body of water and which is calculated as the amount of salt (in grams) dissolved in 1,000 grams (one kilogram) of seawater. The concentration of dissolved salt in a given volume of water and salts are compounds like sodium chloride, magnesium sulfate, potassium nitrate and sodium bicarbonate which dissolve into ions. By measuring the electrical conductivity of solution extracted from a water-saturated soil paste, soil salinity is determined. In another way, the process of increasing the amount of salt in water is called salination. Salinity is the most detrimental stress among all abiotic stress (Shrivastava and Kumar, 2015). The abbreviation of salinity is ECe (Electrical Conductivity of the extract) with units of decisiemens per meter (dS/m) or millimhos per centimeter (mmhos/cm). Both of the units are equivalent of measurement and both has the same numerical value.

There are many plants that are sensitive to soil salinity and the amount of soil salinity is increasing nowadays. Salinity is occurred when salt is accumulated in soil surface and through evaporation and capillary pore it can rise in the soil surface. The adverse use of potassium fertilizer increases salinity.

The growth of plant and development is very much influenced by soil salinity (Vidal *et al*., 2009). It is reported that Salinity causes damaged about 25% of the total irrigated land in the world (Cuartero *et al*., 2006). Salt stress creates simultaneous effect on growth and yield of plant through three direct ways. Firstly, salinity blocks the uptakement of water that causes water stress which is termed as osmotic stress. Because of the ion uptakement in leaves which results reducing of the growth. Na^+ showed as more toxic than other ions (Lopez-Climent *et al*., 2008).

In Bangladesh salinity is one of the vital constraints to potato production usually in coastal region. Agricultural field crops exhibit a multiple spectrum of responses under salt stress. Salinity not only reduces the agricultural production of maximum crops, but also, effects soil physiological and chemical properties and also causes ecological imbalance of the area. The ultimate impacts of salinity result low agricultural productivity, low economic returns and soil erosions (Hu and Schmidhalter, 2002).

2.1.1 Effects of salinity on different traits of potato

The interaction of genotypic stress and variability among different genotypes for different traits are important for the screening of salinity tolerance genotypes. The traits can be agromorphogenic, physiological or nutritional. In this research some agromorphogenic and physiological traits are to be taken to screen salinity tolerant variety. Here, agromorphogenic traits include plant height, number of leaves per plant, number of branches per plant, number of tubers per plant, dry weight of plant, tuber yield per plant etc. Physiological traits include chlorophyll content, proline content, Na^+ and K^+ content. Due to salinity stress these traits could be influenced and altered.

2.1.1.1 Effect of salinity on agromorphogenic traits of potato varieties

Plants perform as a sessile and also sensitive beings because throughout the life cycle they meet a different environmental stresses and its growth and productivity are negatively affected by various environmental factors (Yadav *et al*., 2012; Khan and Singh, 2008 and Tuteja and Sopory, 2008). Salinity is a vital environmental stress factor and becomes critical constraint for crop production (Peethambaran *et al*., 2018 and Rashid *et al*., 2017). It is reported that 30% land loss within next 25 years and up to 50% by the middle of 21st century occurred due to increasing salinization of cultivable land and it is also predicted to have devastating global effects due to salinity (Wang *et al*., 2003).

Potato is classified as moderately salt-sensitive crop (Ahmad and Abdullah, 1979). A salinity level is determined by the electrical conductivity of a saturated soil solution extract. It is reported that if salinity level stands in the range of 4 dS/m or above, the tuber yields can be lower and loss of productivity can be more than 25% (Maianu, 1985).

The volume of tolerance depends on the intensity of salinity, the cultivar involved and the developmental stage of the crop (Haverkort *et al.*, 1990; Miller and Martin, 1987; Levy, 1986). The total responses of potatoes to salinity is generally evaluated in terms of survival, vegetative growth, tuber size or total tuber production (MacKerron and Jefferies, 1988; Flowers and Yeo, 1989; Van Loon, 1981). Under harsh conditions in the Andes wild potatoes, growing are relatively stress tolerant, but comprehensive breeding and selection for traits other than abiotic stress tolerance have resulted in cultivars that are deliberated as moderately salt tolerant (Arvin and Donnelly, 2008).

It is noted that a majority of cultivated plant species and especially widely grown horticultural and cereal crops (Chinnusamy *et al*., 2005) are glycophytes and in the rhizosphere solution they are susceptible to excessive concentration of dissolved ions (e.g. >30 mM or >3.0 dS/m). If the salt concentration and the length of exposure increased in glycophytes during growth or developmental stage salinity may induce different physiological malfunctions, such as osmotic, ionic and different secondary (oxidative) disorders (Zhu, 2001), which known as salt stress.

Alhoshan *et al*. (2021) conducted an experiment to estimate the responses of potato plants at different levels of salinity in case of plant dry mass (PDM), root dry mass (RDM), plant height, number of stems and some mineral elements analysis from aerial parts of potato plants. Two potato cultivars were taken in this experiment namely, Madrid and Alver stone russet. The cultivars were exposed to three levels of salinity (0, 50 and 100 mM). From the result of this study, it was found that salt stress left significant effects on all characters, i.e., biomass and height of potato plants were decreased where Na content was increased significantly with salt stress. As well, the results revealed that there was positive correlation among K content and root dry mass (RDM) in the treatment 50 mM and P content and plant dry mass (PDM) in the treatment 100 mM of salinity. Moreover, from the results it was also revealed that increasing concentrations of salinity level have negative impacts on biomass and plant growth in all tested potato cultivars.

Parthasarathi *et al*. (2021) conducted an experiment where they examined the effects of potato rootstock on physiology, dry mass and yield of tomato scion in pots and irrigated with saline water. Tomato (cv. Ikram), potato (cv. Charlotte) and grafted (cv. Ikram/Charlotte) plants were treated to saline and non-saline water-irrigation treatments which was electrical conductivity 5.0 and 1.0 dS m^{-1}, respectively. From the result it was seen that under saline water irrigation the grafted plants responded with differential root trait with balanced mineral partitioning across plant parts. The plants which are grafted were superior under saline and non-saline water-irrigations in water productivity by 56.8% and 70.5 % over the control plants, respectively. From this experiment it was reported that through distinct changes in dry mass allocation and the induction of mineral-compartmentalization processes, potato rootstock could improve the tolerance of tomato scion to saline water irrigation.

Shahid *et al*. (2020) reported that soil salinization is occurred due to climate change which resulting in the losses of crops throughout the world. The ability of a plant tolerance against salt stress is determined by various biochemical and molecular pathways. In this report they mentioned that by the formation of organic and inorganic osmolytes accelerated antioxidant activities and osmotic adjustment are significant and effective on salinity tolerance mechanisms for crop plants. In addition, it was also added that salt tolerance is improved through polyamines by regulating various physiological mechanisms and also including rhizogenesis, somatic embryogenesis, maintenance of cell pH, and ionic homeostasis. In this research project three strategies to augment salinity tolerance capacity in agricultural crops like salinity-induced alterations in signalling pathways, signalling of phytohormones, channels of ions and biosensors, the expression of ion transporter genes in crop plants (especially in comparison to halophytes) were focused.

Ahmed *et al*. (2020) carried out an experiment where they used in vitro method to reveal variability in salinity stress tolerance of potato varieties. In this experiment stem cuttings consisting of a single node of different varieties were cultured on Murashige and Skoog (MS) medium supplemented and treated with different concentrations of sodium chloride (0, 50, 100 and 150 mM). The result showed that all NaCl (sodium chloride) concentrations influenced negatively the length of plantlets, number of branches, number of nodes, number of the leaflets, leaflet width, leaflet length, root length, number of the roots, fresh plantlet weight, dry plantlet weight of all varieties. Also reported that at high concentrations (100-150 mM) microtuberization and stolon growth of the varieties were also completely reduced.

Sahin *et al*. (2020) performed an experiment to reveal the effects of different salt concentrations (100, 200 and 300 mM) on microtuberization of potato. Here four cultivars were taken to run the experiment and they were Slaney, Granola, Rasin Busset and Agria. To detect expression levels of dehydration-responsive element binding 2 (StDREB2) transcription factor was used in the transcriptional regulation of gene expression to various salt stresses in potato. The result showed that the production of microtubers of all the cultivars was negatively influenced and decreased with increased salt intensity. The cultivar Slaney given the highest explant ratio forming micro tuber (66.6%) and the highest number of micro-tubers (0.88) micro tubers/explant). But on the other side under salt stress conditions Granola could not produce any microtuber. For various NaCl concentrations the RT-qPCR regarding StDREB2 relative gene expression levels showed noticeable differences among potato genotypes. In this study it was noticed that at 100 mM and higher salt concentrations StDREB2 gene relative gene expression level was also up regulated for almost all the cultivars except cv. Granola.

Rashid *et al.* (2020) performed an experiment to screen salt tolerance genotype under in vitro bioassay condition in Bangladesh where they used ten native and six exotic potato genotypes. In addition to MS medium and evaluated salt tolerant and sensitive genotype, five different concentrations of NaCl (0= control, 100, 150, 200 and 250 mM) were used. Among the genotypes, the ANOVA, DMRT and correlation coefficient results were found highly significant at $p< 0.01$. Stem length and internodal distance, leaves number, roots number, root length, dry weight of whole plant and fresh weight of whole plant with salt stress condition showed highly positive correlation, co-efficient. Depending on stress tolerance trait indices (STTIs), Arun (92.78) and Ausha (80.27) performed as a highest salt tolerant, Jamalu (56.33) and Chollisha (57.03) performed as the most salt sensitive potato cultivars.

Li *et al.* (2018) conducted a study by using in vitro cultures and demonstrated that salt or virus infection (singly and in combination), and co-stress by virus infection (singly and in combination) significantly hampered growth and microtuber production and caused serious oxidative cell damage which is determined by levels of O^{2-} and methane dicarboxylic aldehyde and H_2O_2 localization in situ. Virus and salt are believed to be responsible for the reduced growth and production eventually resulting in decreased tuber yield.

Zainab *et al.* (2018) studied the response and behaviour of two mutant clones of potato genotype for salt stress. The potato genotypes were exposed to different salt levels of sodium chloride (with electrical conductivity of 8, 10, 12 dSm^{-1}) and they were compared with those in the control treatment 6 dSm^{-1}. The results of this study showed a significant decrease in the morphological characteristics of the vegetative growth (number of shoots, plant height and dry weight) and tuber formation with the increasing salt levels. But the characteristics of the root growth (number of roots, lengths and dry weight) were not affected. There was no significant difference found under saline levels in the behaviour of the two clones except for the superiority of vegetative clone (C2) at comparison treatment in the number of shoots (2.00 shoot/ plant), and vegetative clone (C1) at comparison treatment and 12 ds m^{-1} in the shoot length and the percentage of tuber formation (13.40 cm and 100% Respectively). From this study it was recorded that at 12 dSm^{-1} the root growth of vegetative clone (C2) had a significant accumulation of Na^{+} and Ca^{++} which reached 8.33 and 23.38 mg^{-1} gm dry weight respectively and on the other side in the control treatment, the accumulation of K^{+} in vegetative clone (C1) was increased by the root growth which reached 45.03 mg $^{-1}$ dry weight.

Murshed *et al*. (2018) worked on nine varieties of potato (*Solanum tuberosum* L.) to screen for salt stress tolerance. Salt stress was determined by adding 25, 50, 75, 100, 125, 150 and 200 mM of NaCl to Murashige-Skoog (MS) medium where they compared to MS medium without NaCl. From this study it was found that salt stress adversely restricted the plant growth, and varieties differed in their responses. With the increase of NaCl levels progressive reduction was seen in the studied parameters. From the result of this study it was concluded that Taurus and Sultana varieties performed as salt tolerant, four varieties namely, Loane, Diamant, Amarin, and Sylvana performed as moderately salt tolerant and three varieties namely, Toscana, Soraya, and Kenita performed as salt sensitive.

Biswas *et al*. (2017) executed an experiment to select salt tolerant cultivars with the comparison of the salinity level between indigenous and modern cultivars. In this study local and modern potato cultivars were investigated through the in vitro selection with five levels of NaCl (0, 30, 60, 90 and 120 mM). Here Challisha and modern cultivars Diamant and Felsina were used as indigenous potato varieties. In response to different levels of NaCl, remarkable differences were seen among the cultivars. Gradually reduction of plant growth and root development was seen with increased concentration of NaCl. All three cultivars were performed well with exhibiting different growth status up to 60 mM NaCl, but at 120 mM of NaCl they performed poorly. Cultivar Challisha showed better performance in case of shoot length, root length, the number of nodes per plantlet and the fresh weight per plant up to 90 mM of NaCl.

Munira *et al*. (2015) conducted an experiment to screen salt tolerant varities of potato where Sagita gave the highest yield followed by Felsina, Lady Rosetta and Provento. From the result it was found that leaf chlorophyll content, membrane leakage, per plant tuber weight, and ion uptake were far better in Sagita and Felsina. The variety Shilbilati and Lalpakri exhibited upto 69.45% membrane injury where variety Sagita followed by Felsina had less membrane injury upto 32.14% at 6.95 dS/m of salinity. Finally, the results revealed that under salinity stress condition, variety Sagita and Felsina responded well. Lady Rosetta and Provento performed as moderately salt tolerant at 6.95 dS/m and the varieties Shilbilati and Lalpakri were performed as salt sensitive among the selected varieties.

Sudhersan *et al*. (2012) explained that salinity is a vital problem for potato cultivation in Kuwait. In order to screen salt tolerant cultivars an experiment was made to screen many potato cultivars using tissue culture technology. Potato cultivars Ajiba, Almera, Anabelle, Arnova, Atlas, Bellini, Charlotte, Costanera, Desiree, Diamond, Fontane, Lola, Maria Tropica-1, MF-1, MF-II, Matador, Nicola, Primavera, Rembrandt, Safrane, Santae, Spunta, Tacna, Timate, and Unica were selected and established in tissue culture media via meristem culture technique using Murashige and Skoog (MS) shoot proliferation medium. Stem nodal segments were taken and planted on MS culture media which was treated with different concentrations of NaCl (0, 750, 1000, 2000, 3000 and 4000 ppm). In order to the elongation percentage of shoot against salt stress, the cultivars were classified as tolerant, sensitive and highly sensitive to salinity. The levels of salt toxicity and related morphological symptoms on plant growth were also examined for each cultivar. This study helped to figure out the salt tolerant potato cultivars which is suitable for cultivation in Kuwait and other countries in where potato production is declined due to soil salinity.

Homayoun *et al*. (2011) reported that in saline lands cultivation of potato has broadly significance in Iran. In Iran fifteen percent of total lands are saline and semi saline lands. In saline soil the cultivars of potato show different reaction. Marphona cultivar is more sensitive to salinity stress in comparison with Agria cultivar. In this experiment the effect of different salinity concentrations (0, 50, 100 and 150) mg/l NaCl were evaluated in green house conditions on Agria and Marphona cultivars to estimate their reaction to salinity. At first, in MS medium the plantlets were grown without hormone and were sent out from growth chamber and transfered in tunnel. After a week, the vases were shift out from tunnel and placed in green house conditions where different salinity concentrations (0, 50, 100 and 150) mg/l NaCl were applied on them. After two months, the number, length and diameter of lateral branch were measured and the number, weight, diameter and buds of mini tubers were also measured. From the result it was showed that salinity stress in Agria variety has a multiple effect on the number of mini tubers but the diameter and number of buds in mini tubers reduced with the increase of salinity stress.

Karim *et al*. (2011) conducted an experiment where ten exotic potato varieties (var. All Blue, All Red, Cardinal, Diamond, Daisy, Granola, Green Mountain, Japanese Red, Pontiac and Summerset) were used to determine their yield potentiality. From the result the highest total tuber weight per plant (344.60g) was recorded in var. Diamond and the lowest total tuber weight per plant (65.05g) was recorded in variety All blue. The variety Daisy given the highest number of tuber (57.52) per plant and the lowest number of tuber (8.82) per plant was reported in Red varieties.

According to Akbarimoghaddam *et al*. (2011), salinity effects are the outcomes of complex interactions among morphological, physiological, and biochemical processes including seed germination, plant growth and water and nutrient uptake. Salinity affects almost all parts of the plant development including: germination stage, vegetative growth and reproductive developmental stage. Soil salinity causes ion toxicity, osmotic stress, nutrient (N, Ca, K, P, Fe, Zn) deficiency and oxidative stress on plants and these activity limits water uptake from soil. According to Bano and Fatima (2009), soil salinity reduces plant phosphorus (P) uptake significantly because phosphate ions precipitate with Ca ions.

An experiment was carried out where twenty five varieties were evaluated at six locations. In this study they found that the plant height (cm) in case of Diamond (47.87), Sagitta (56.20), Quincy (95.40); No. of stems per hill in Diamond (3.66), Sagitta (2.53), Quincy (2.26); foliage coverage at 60 DAP (%) was found in Diamond (73.33), Sagitta (93.67), Quincy (92.00); No of tuber per hill in Diamond (6.72), Sagitta (3.94), Quincy (9.95) were recorded; the total weight of tuber per hill (kg) in Diamond (0.30), Sagitta (0.34), Quincy (0.35); dry matter content (%) was recorded in case of Diamond (19.54), Sagitta (20.10), Quincy (18.70) (BARI, 2009 a). Another field trial with twenty eight varieties was evaluated at different five locations in second generation. They figured out that, the plant height at 60 DAP (cm) was recorded in case of Diamond (54.13), Sagitta (47.27), Quincy (80.93); number of stem per hill in Diamond (4.66), Sagitta (5.40), Quincy (5.80) were recorded; foliage coverage of potato plant at 60 DAP (%) in Diamond (93.67), Sagitta (90.67), Quincy (97.00). The total number of tubers per hill was reported in Diamond (8.11), Sagitta (5.41), Quincy (6.95); weight of tubers per hill (kg) in Diamond (0.28), Sagitta (0.37), Quincy (0.45) respectively. The dry matter content (%) was recorded in case of Diamond (19.91), Sagitta (20.60), Quincy (18.34) (BARI, 2009 b).

An experiment with twelve varieties were estimated at six locations in their third generation. Plant height (cm) was found in case of Diamond (50.93), Granola (69.10), Sagitta (41.33), Quincy (65.87) were recorded. Number of stem per hill in case of Diamond (5.66), Granola (3.20), Sagitta (3.46), Quincy (4.86); foliage coverage at 60 DAP (%) in case of Diamond (92.00), Granola (91.00), Sagitta (89.33), Quincy (96.00). The number of tuber pet hill in Diamond (7.24), Granola (6.82), Sagitta (5.23), Quincy (5.76) were noted. The total weight of tuber per hill (kg) in Diamond (0.38), Granola (0.26), Sagitta (0.33), Quincy (0.35) was reported; dry matter content (%) in Diamond (20.80), Granola (20.45), Sagitta (19.80), Quincy (18.40) was also reported (BARI, 2009 c).

Another one experiment with seven potato varieties was conducted at MLT site. In this study it was found that plant height (cm) in Diamond (43.00), Lady Rosetta (37.00), and Courage (44.47); number of stems per plant in case of Diamond (3.57), Lady Rosetta (2.80), and Courage (3.67); number of tubers per plant in case of

Diamond (8.07), Lady Rosetta (5.67), and Courage (6.70) was calculated (BARI, 2009 d).

Haque (2007) conducted a field experiment in where he used 12 exotic potato germplasm to determine their suitability as a variety in Bangladesh. From this experiment it was reported that all the varieties gave more than 90% emergence at 20-35 DAP. It was reported that plant height (cm) of Quincy was (87.8), Sagitta (65.8), Diamond (62.6); number of stems per hill was found in Diamond (7.2), Quincy (4.5), Sagitta (4.4); plant diameter (cm) was recorded in case of Sagitta was (4.0), Quincy (3.7), Diamond (2.6) at 60 DAP; foliage coverage (%) of Sagitta was (100.0), Diamond was (98.3), Quincy was (96.6); number of tubers per plant was reported in case of Diamond (13.06), Sagitta (8.34), Quincy (6.71); The total weight of tubers per plant (kg) of Quincy was (0.64), Sagitta was (0.63), Diamond was (0.49); the total dry matter content (%) of Sagitta was (20.8), Diamond (20.1), Quincy (18.5).

Mahmud *et al*. (2009) evaluated the yield of seed size tubers in five standard potato cultivars (Cardinal, Multa, Ailsa, Heera, and Dheera) in a Seed Potato Production Farm, Debijong, Panchagarh in relation to dates of dehaulming (65, 70, and 80 days after planting). Cardinal gave the maximum seed tuber yield at 80 DAP followed by Heera and Cardinal at 70 DAP, Dheera and Ailsa at 75 DAP.

Rahman *et al*. (2008) carried out an experiment where he worked on the salinity (NaCI) effects on three potato cultivars (Atlanta, Shepody and Shilbilaty). Five NaCI levels (0, 25, 50, 75 and 100 mM) treatment were used. The cultivars showed significant differences in different NaCl levels. In MS media salinity stress gradually reduced plant growth and root development with increased NaCl concentration. At high NaCl (100 mM) all the cultivars survived in MS media with exhibiting different growth status. The results showed that Shilbilaty performed better in case of shoot length and shoot fresh mass than Shepody and Atlanta. It was also reported that at different NaCl media the Atlanta performed better in root growth than Shepody and Shilbilaty. It was reported that highest salinity level drastically inhibits root growth in all the cultivars tested. The control and 25mM NaCl containing MS media did not affect the growth traits of potato plantlets in in vitro condition. Overall result showed that control was found superior in growth characterized than the rest of the tested NaCl levels.

Mondol (2004) studied the performance of seven exotic (Dutch) varieties of potato. From this study, plant height (cm) of Diamond was found (18.07), Granola (13.47). The number of main stem per hill in case of Diamond (4.36), Granola (4.90). The number of tubers per hill of Diamond (12.00), Granola (10.93); weight of tubers per plant (kg) was reported in case of Diamond (0.57), Granola (0.39); Dry matter (%) of Diamond was (17) and Granola (16.30).

Rabbani and Rahman (1995) carried out an experiment to estimate the performance of 16 Dutch potato varieties in their third generation. It was recorded that the height of the plants varied among the varieties significantly. The highest foliage coverage at maximum vegetative growth stage was recorded in the variety Cardinal (93.3%) followed by Diamond. The highest yield of tubers per hectare was found in Cardinal (35.19 t ha^{-1}) followed by Romano (30.09 t ha^{-1}) and the lowest was obtained from stroma (11.11 t ha^{-1}).

2.1.1.2 Effect of salinity on physiological traits of potato varieties

In order to estimate the tolerance of plants against salinity stress, growth or survival of the plant is measured because salinity integrates the up or down-regulation of many physiological mechanisms which is occurred within the plant. Osmotic balance is necessary for growing of plants in saline medium. And this balance is hampered due to salinity and this balance results in loss of turgidity, cell dehydration and ultimately death of cells. On the other hand, according to Ashraf (2004), excessive effects of salinity on plant growth may also result from impairment of the supply of photosynthetic assimilates or hormones to the growing tissues. Ion toxicity is responsible for the replacement of K^+ by Na^+ in biochemical reactions, and Na^+ and Cl^- induced structural changes in proteins is occurred.

If the sodium in cell walls accumulates excessively, it can rapidly lead to osmotic stress and cell death (Munns, 2002). Plants sensitive to these elements may be affected at relatively low salt concentrations even the soil contains enough of the toxic element. Because many salts are also performed as plant nutrients, high salt levels in the soil can effect or upset the nutrient balance in the plant or can restrict with the uptake of some nutrients (Blaylock *et al.*, 1994).

Salinity also affects photosynthesis activity usually through a reduction in leaf area, chlorophyll content and stomatal conductance, and to a lesser extent through a reduction in photosystem II efficiency (Netondo *et al.*, 2004). Salinity affects reproductive development adversely by preventing microsporogenesis and filament elongation, increasing programmed cell death in some tissue types, causes ovule abortion and senescence of fertilized embryos. The saline growth medium results many excessive effects on plant growth, due to a lower osmotic potential of soil solution (osmotic stress), specific ion effects (salt stress), nutritional imbalances or a combination of these factors (Ashraf, 2004). All these factors create adverse reduction on plant growth and development at physiological and biochemical levels (Munns and James, 2003) and also at the molecular level (Tester and Davenport, 2003). It was reported that K^+ acts as cofactor for several enzymes and cannot be replaced by Na^+. High level of K^+ concentration is also needed for binding tRNA to ribosomes and thus protein synthesis (Zhu, 2002). Metabolic imbalance is also happened due to ion toxicity and osmotic stress, which in turn leads to oxidative stress (Chinnusamy *et al.*, 2006).

At the time of reproductive phases, the effects of salinity show more adversely on plant development. The harmful effects of salinity may be attributed to salinity-stress effect on the cell cycle and differentiation. Salinity blocks the cell cycle transiently by reducing the expression and activity of cyclins and cyclin-dependent kinases and these result in fewer cells in the meristem, thus limiting growth. During salt stress the activity of cyclin-dependent kinase is diminished also by post-translational inhibition. Recently it is reported that salinity seriously affects plant growth and development, restricts seed germination, seedling growth, enzyme activity (Seckin *et al.*, 2009), DNA, RNA, protein synthesis and mitosis (Tabur and Demir, 2010)

Salinity stress tolerance by plants primarily relays on the genotype that determined alterations on processes like uptake and transport of salt by roots, together with metabolic and physiological events (Winicov, 1994). Selection of different cultivars of potato for abiotic stress tolerance was essential not only for breeding to abiotic stress, but also for providing better material for studying the abiotic stress tolerance mechanism (Sergeeva *et al.*, 2000).

Osmotic stress is caused by salinity is the primary reaction triggered by relatively low or moderate salinity levels, reduction of soil water potential i.e. hinders water uptake and causes possible cell dehydration (Ondrasek *et al*., 2009). For that reason, increased concentration of dissolved salts may cause imbalance and reduce soil water potential from -1 to -2.5 (-5 in extreme cases) MPa (Flowers and Flowers, 2005). It was noted that in saline conditions, osmotic pressure in the rhizosphere solution exceeds that in root cells, modify water and nutrient uptake. After that plant responses to osmotic stress are the closure of stomata (partially or fully) i.e. transpiration or the reduction carbon assimilation, reduction in cell growth and development, reduced leaf area and chlorophyll content, accelerated defoliation and senescence i.e. mortality of plant organism (Shannon and Grieve, 1999).

An increase in concentration of certain dissolved ions, will enhance ionic stress, and cause phytotoxic effects (e.g. Cl, B, Al toxicity). Specific ionic stress condition cause disruption of selectivity of root plasma membrane, homeostasis of essential ions and the activities of numerous metabolic (Zhu, 2001). For instance, rice is known as one of the most worldwide grown cereals and salinity acts as the main limiting variable of mineral nutrition (Marschner, 1995). However, around half of the global saline (i.e. alkaline) soils used for cereal production which are overlain on soils with low levels of plant-available Zn ie. Zn-deficient soils, due to Zn complexation/competition with dissolved salts (CO_3s, SO_4s, Na^+) at alkaline pHs (Ondrasek *et al*., 2009). Therefore, it was reported that the food crop consumption plays the principal route of most essential minerals into the human body. Salinity may contribute to mineral deficiency in billions of people indirectly.

The salinity effects primary give rise to various secondary ones such as oxidative stress which is characterised by accumulation of reactive oxygen species (ROS: H_2O_2, O_2, -OH), potentially harmful to bio-membranes, proteins, nucleic acids and enzymes (Gomez *et al*., 2004). Detoxication of ROS is enhanced due to some antioxidative enzymes such as superoxide dismutase (SOD), catalases, peroxidises, etc. The relatively salt-tolerant species (e.g. pea genotypes) is responsible for increase of the activities of certain antioxidative enzymes. Whereas Na^+ causes a stronger inhibition effect on particular SOD forms than Cl ions in salt-sensitive species (e.g. cowpea) (Hernandez *et al*., 1994).

Na^+ and Cl^- are the two most important ions that induce salt stress in plants. Sodium is nonessential but beneficial element for the plant, whereas Cl plays an important role as phyto-micronutrient (Marschner, 1995). However, in excessive concentrations both are potentially toxic and they trigger specific disorders and create substantial damages to crops. Under adverse Na^+ and Cl^- rhizosphere concentration, there are competitive interactions with other nutrient ions (K^+, NO_3^-, $H_2PO_4^-$) in root cells for binding sites and transport proteins and after that for (re)translocation, deposition and partitioning in the plant (Grattan and Grieve, 1999; Tester and Davenport, 2003; White and Broadley, 2001). Ondrasek *et al*. (2009) conducted a study where under moderate (60 mM) NaCl salinity significantly enhanced uptake and accumulation of Na and accompanied with a decrease in K concentration in the same tissues (from ~30% in strawberry and ~40% in radish to 4-folds in muskmelon) was obtained.

In the same studies, it was found that salinity stress reduced all vegetative parameters (e.g. number of strawberry runners by up to 7-folds and length of the longest runner by 3-folds). Total fruit yield (in radish by 35%, muskmelon by 50% and strawberry by 60%) was also decreased under saline condition and acceleration of leaf senescence. Reduction of the strawberry growing period by up to 22 days i.e. induced plant mortality after 65-day treatment with salinised (60 mM NaCl) nutrient solution. In marginal zones salinity tolerance plays an important character in plant breeding to increase yields (Turkan and Demiral, 2009). After the application of conventional selection and modern breeding techniques, significant improvements in the salinity tolerance of agriculturally important plants has been achieved (Ashraf and Harris, 2004), although these techniques are long and costly. This breeding methods especially apply to the selection of fruit plant material, due to the long periods of growth is required and strategies are needed to shorten this process.

For the study of salt stress into in vitro culture has issued as a useful technique (Naik and Widholm, 1993; Woodward and Bennett, 2005), and it is also being useful for the selection of tomato and *Vigna radiata* plants tolerant of salinity (Hassan *et al*., 2008).

Moreover, the accumulation of solutes such as glycine and proline have been connected to water stress, salinity and other abiotic plant stresses (Lu *et al*., 2009 and Ashraf and Harris, 2004), and indicating a vital role for these solutes in case of olerance to these stresses.

Under salt stress proline accumulates in both leaf and root tissues (Aziz *et al.*, 1999) and secretly protects against the osmotic potential which is generated by salt (Chen *et al.*, 2007; Watanabe *et al*., 2000). Studies over the last years on salinity effects have revealed a number of important strategies to improve salt tolerance. One strategy is reported as the controlled influx of Na^+ into the root cells. A comparison of Na^{+-}influx in root cells of the glycophyte *Arabidopsis thaliana* and those of the halophyte *Thellungiella halophila* revealed that in the halophyte species, ion channels are much more selective for Na^+ than those of Arabidopsis (Volkov and Amtmann, 2006).

By the transportation through the xylem excess Na^+ ions that reaches the transpiration stream in the root system are destined for the shoot. Moreover, plants are capable to absorb Na^+ from the xylem sap to surrounding tissue by means of Na^+ transporters that belong to the HKT gene (Sunarpi *et al.*, 2005).

Plants are well adapted to salt like halophytes and these plants have a high capacity to accumulate Na^+ ions in the large central vacuole. Isolating Na^+ ions into vacuoles has a big impact on the cellular osmotic potential (Flowers and Colmer, 2008).

In response to salt stress plants produce osmotically active solutes like proline to balance the water potential of the cytosol with the apoplast and vacuolar lumen, (Szabados and Savoure, 2010). Besides regulation of osmotic pressure, proline has been shown to stabilize proteins and membrane and protect plants from free radical-induced damage and also proline maintains appropriate $NADP^+$/NADPH mechanisms (Mansour, 1998). A key mechanism in proline metabolism is the reciprocal regulation of the proline biosynthesis gene P5CS1 and the proline degradation gene PDH (Szabados and Savoure, 2010; Peng *et al*., 1996). During salt stress, P5CS1 is induced and PDH is repressed (Strizhov *et al.*, 1997; Peng *et al*. 1996). Over-expression of the P5CS gene from *Arabidopsis* in potato strongly stimulated proline production particularly in the presence of 100 mM NaCl and improved salinity tolerance with respect to tuber yield and weight (Hamida *et al.*, 2005).

Once Na^+ enters inside the cytosol of plant cells and is not sequestered in the vacuole, it may interfere with the activity or function of (K^+) as a co-factor for a range of enzymes, because Na^+ replaces K^+ physically but not functionally (Shabala *et al.*, 2008). During salt stress the ability to maintain K^+ homeostasis is considered a characteristic of more salt tolerant plants (Hauser and Horie, 2010; Shabala *et al*., 2008).

Hamooh *et al.* (2021) performed and conducted a study. And in this study they approached in vitro condition to compare the tolerance of potato cultivars ‘BARI-401’ (red skin) and ‘Spunta’ (yellow skin). MS media was supplemented with lithium chloride (LiCl 20 mM) and mannitol (150 mM) to simulate ionic and osmotic stress. To determine metabolite accumulation GC-MS and spectrophotometry techniques were used. Other biochemical properties, such as total phenols concentration (TPC), total flavonoids concentration (TFC), antioxidant capacity (DPPH free radical scavenging capacity), polyphenol oxidase (PPO), and peroxidase (POD) activities, were also evaluated. From this study it was reported that two cultivars showed different reaction to ionic and osmotic stress treatments, with Spunta accumulating more defensive metabolites in response, indicating a higher level of tolerance.

Akrimi *et al.* (2021) carried out an experiment to evaluate the influence of electromagetic treatment of saline water on agro-physiological and antioxydative responses of potato. Three potato varieties (Spunta, Bellini and Alaska) were taken, over two growing seasons and three drip irrigation treatments were applied such as, saline water (SW), electromagnetic saline water (MSW) and ground water (C). In this experiment phenology, agro-physiological and biochemical traits were estimated along the growth cycle. The result of this experiment showed that, under SW and MSW condition phenological response was similar. It was also noted that MSW treatment enhanced the yield, photosynthesis, and chlorophyll fluorescence. Plants treated with the irrigation of SW treatment showed higher membrane lipid peroxidation (MDA), antioxidant enzymes and soluble sugar content in their leaves. Alaska was performed as less responsive to salinity because it exhibits delayed implementation of antioxidative enzymes and less MDA and H_2O_2 contents. From the result it was concluded that under saline conditions MSW might be beneficial for potato cultivation.

Mousavi *et al.* (2020) studied an experiment to investigate the effect of salinity levels on physiological and biochemical properties and tuberization yield of potato in where potato cultivar Agria was selected to culture in MS culture medium. In this experiment salinity stress assessment was estimated and studied in a fluid environment. The effects of salinity stress on different stages of seedling growth in vitro conditions and the activity of photosynthetic and enzymatic pigments were measured using spectrophotometric measurements. The result of data analysis of variance showed that photosynthetic pigments were reduced due to salinity and at a concentration of 50 mM, it is resistant to the addition of compounds such as soluble sugars, proline and antioxidant activity but at higher concentrations (75 and 100 mM), the plant is likely to be shown as severely damaged due to excessive growth in active oxygen species. Moreover, with the increase in antioxidant activity, it indicates an increase in the removal of active oxygen species and to increase salinity tolerance this feature is often used as an indicator.

Demirel *et al.* (2020) did an investigation to identify the key mechanisms and processes underlying single and combined abiotic stress tolerance by comparative analysis of tolerant and susceptible cultivars of potato. From this experiment the physiological data showed that the cultivars Desiree and Unica were performed as stress tolerant while Agria and Russett Burbank were performed as stress susceptible. A greater reduction of photosynthetic carbon assimilation in the susceptible cultivars was caused due to abiotic stress which was associated with a lower leaf transpiration rate. The result of stress treatment showed in increases in ascorbate peroxidase activity in all cultivars except Agria in where increased catalase activity in response to stress. Transcript profiling highlighted a decrease in the abundance of transcripts encoding proteins associated with PSII light harvesting complex in stress tolerant cultivars. Furthermore, stress tolerant cultivars accumulated fewer transcripts encoding a type-1 metacaspase implicated in programmed cell death. Stress tolerant cultivars exhibited stronger expression of genes associated with plant growth and development, hormone metabolism and primary and secondary metabolism than stress susceptible cultivars.

Mahmoud *et al.* (2020) conducted two open field experiments in salt-affected sandy soil to investigate plant growth, physiology, and yield of potato in response to soil salinity stress under single or combined application of Zn, B, Si, and Zeolite nanoparticles. It was predicted that soil application of nanoparticles could be enhanced plant growth and yield by alleviating the adverse impact of soil salinity. Usually, all the nano-treatments applications significantly enhanced plant height, shoot dry weight, number of stems per plant, leaf relative water content, leaf photosynthetic rate, leaf stomatal conductance, chlorophyll content and tuber yield with the comparison of the untreated control. Moreover, the concentration of nutrients (N, P, K, Ca, Zn, and B) in plant tissues, leaf proline, and leaf gibberellic acid hormone (GA_3) in addition to contents of protein, carbohydrates, and antioxidant enzymes (polyphenol oxidase (PPO) and peroxidase (POD) in tubers were increased due to soil application of these treatments. With the comparison to the other treatments, the combined application of nanoparticles showed the highest plant growth, physiological parameters, endogenous elements (N, P, K, Ca, Zn, and B) and also showed the lowest concentration of leaf abscisic acid (ABA) and transpiration rate. This result suggested that to improve crop productivity in salt-affected soils, soil addition of the aforementioned nanoparticles can be a promising approach.

Zhu *et al.* (2020) did an experiment to explore the role of StMAPK3 in response to salt and osmosis stress in potato. In this experiment polyethylene glycol (PEG) (5% and 10%) and mannitol (40 mM and 80 mM) were used to induce osmosis stress. Potato plant was cultured with NaCl (40 mM and 80 mM) to induce salinity stress, StMAPK3 overexpression and RNA interference-mediated StMAPK3 knockdown were implemented to explore the activity of StMAPK3 in potato growth, stomatal aperture size, activity of superoxide dismutase (SOD), catalase (CAT) and peroxidase (POD), and contents of H_2O_2, proline and malonaldehyde (MDA). After that, transpiration, net photosynthesis, stomatal conductance, and water use efficiency were detected and also subcellular location of StMAPK3 protein was detected. In potato plants PEG, mannitol and NaCl treatments induced the accumulation of StMAPK3 mRNA. It was marked that StMAPK3 protein was situated on the membrane and nucleus. Potato phenotypes, enzyme activity of SOD, CAT and POD, as well as H_2O_2, proline and MDA contents were changed due to abnormal expression of StMAPK3 under osmosis and salinity stress. StMAPK3 regulated photosynthesis and stomatal aperture in potato treated by PEG, mannitol and NaCl. From this result it was stated that modulation of potato phenotypes and physiological activity denotes StMAPK3 as a regulator of osmosis and salinity tolerance.

Aydoğan *et al.* (2020) did an investigation to find out the varietal differences in salinity tolerance of potato (*Solanum tuberosum* L.) plants by connecting the overall salinity tolerance with changes in different morphological and physiological characteristics. There were nineteen potato cultivars were taken and grown under controlled conditions in greenhouse at 25-18 (±2) C (day/night), 70% relative humidity under non-saline and 5dS m-1 NaCl conditions for 90 days. For this experiment, tubers were planted in pots which was 14L containing soil: peat: vermiculite (3: 1: 1). Salt treatment was started when all the seedlings where emerged and it was taken 1 week to emerge. Salt stress tolerance of potato plants were estimated with visual damage scale, cell membrane injury analysis and malondialdehyde (MDA) content, the indicator of lipid peroxidation. In this study, leaf relative water content (RWC), loss of turgidity (LT) and total soluble protein (TSP) content were also evaluated. In addition, potato with the use of SDS-PAGE the protein profiles of leaf tissues of plants were evaluated. It was concluded that, among 19 potato cultivars cvs. Bettina, Challenger, Granola, Lady Claire, Musica and Orchestra were performed as the most susceptible, cvs. Desiree and Russet Burbank were performed as the most tolerant to salt stress. The data showed that the low cell membrane injury and MDA content made cvs. Desiree and Russet Burbank relatively salt-tolerant cultivars. Also from this experiment it was also reported that, in salt stress tolerance of potato cultivars visual damage scale and SDSPAGE protein profiles could be used as biomarkers.

Sobieh *et al*. (2019) carried out a study to estimate the survival percentage of two potatos (*Solanum tuberosum* L.) cultivars (Spunta and Valor) under salt stress condition. In this study Some biochemical alterations and ultrastructural responses of plantlets were evaluated. Moreover, genetic diversity was also estimated by the help of RAPD technique. The funding showed that, there was a significant decrease in the survival percentage, significant accumulation of osmoprotectants (proline) and induction of DNA damages with the increase of external stress. There were also seen the closing of stomatal apertures, changes in chloroplast ultrastructure and cell intercellular spaces markedly decreased. Additionally, complete inhibition of plantlet growth was seen at high salt stress (150 and 200mM NaCl).

Kafi *et al.* (2019) said that in crop production such as potato salinity of irrigation water is an important limitation factor in worldwide. They conducted an experiment and in this field experiment the effects of silicone compounds on potato (cv. Agria) performance was evaluated during 2016 cropping season in Iran. Irrigation salinity [0.3 (non-stress), 5, 8 and 12 dSm^{-1}] and foliar application of potassium sulphate (1000 ppm), sodium silicate nanoparticles (400 ppm) and silica (1000 ppm) taken as treatments. From the results it was indicated that salinity was responsible to decrease transpiration rate, stomatal conductance, quantum yield of PSII, membrane stability index, carotenoids, tuber number per plant and tuber yield while it enhanced water use efficiency and tuber dry matter percentage. Quantum yield of PSII, carotenoids content, DPPH radical scavenging activity, tuber number per plant, tuber yield and tuber dry matter percentage were affected positively by the foliar application of anti-stress compounds. Although most biochemical and photosynthetic traits were improved with the application of all compounds but ameliorative effect of the two silicon compounds, especially sodium silicate nanoparticles was more evident.

Efimova *et al.* (2018) did a reseach in where the mechanisms of potato (*Solanum tuberosum* L.) plants' tolerance were investigated in cv. Lugovskoi regionalized in Russia under chloride saline condition. Regenerated plants were grown in vitro from apical meristem and produced on half-strength Murashige and Skoog medium (0.5 MS) using a hydroponic unit in controlled-climate conditions. The plants were exposed to salt stress (50–150 mM NaCl, 7 days) At the age of six weeks. Plant response to salt stress was examined by growth parameters and physiological characteristics. In response to salinity it was found that the plants of potato, cv. Lugovskoi, showed a considerable inhibition of growth processes, reduction in chlorophyll a content, and suppression of stolon formation and this pointed to a rather low salinity tolerance of the cultivar. Moreover, the plants preserved water homeostasis owing to effective osmoregulation, actively accumulated proline that acted as a stress protector and showed hardly any signs of oxidative stress under weak or moderate salt stress condition. It was reported to be assumed that low salt tolerance of this cultivar depended on the inability of its root system to retain sodium ions and also ensured selective ion transport to the aboveground part of the plant and on inefficiency of the system of sodium ions removal from the cytoplasm of leaf cells and their compartmentalization in the central vacuole to reduce their toxic effect.

Jaarsma *et al.* (2018) reported that potato is an important cultivated crop species. Though it is moderately salt sensitive but there is a need to develop more salt tolerant cultivars. An experiment was conducted where they compared the activity, gene expression and protein levels of the vacuolar proton pumps and the Na^+/H^+ antiporters in two potato cultivars (*Solanum tuberosum*) contrasting in their salt tolerance (cv. Desiree; tolerant and Mozart; sensitive). The cultivars were grown at 0 mM and 60 mM NaCl. To study the pump activity and protein levels of the V-H^+-ATPase and the V-H^+-PPase and the activity of the Na^+/H^+ antiporter, tonoplast enriched vesicles were used. Although salt stress decreased the V-H^+-ATPase and the V-H+-PPase activity in both cultivars, the decline in H^+ pump activity was more serious in the salt sensitive cultivar Mozart. Protein amounts of the vacuolar H^+ pumps decreased in Mozart after salt treatment but remained unchanged in the cultivar Desiree. In Mozart decreased protein amounts of the V-H^+-PPase found and may explain the reduced V-H^+-PPase activity found for Mozart after the application of salt stress. Protein amounts of V-H^+-PPase were equal in both cultivars under non-stress conditions and after salt treatment in the cultivar Desiree the V-H^+-PPase activity was already twice as high and remained higher as compared to Mozart. This cultivar dependent V-H^+-PPase activity may be explained the higher salt tolerance of Desiree. Moreover, Mozart showed a lower Na^+/H^+ exchange activity and the Km for Na^+ is at least 2-fold lower in tonoplast vesicles from Desiree when combined with reduced vacuolar H^+ pump activity and from this result suggested that as compared to Mozart, NHXs from Desiree have a higher affinity for Na^+.

Gowayed *et al.* (2017) conducted a study and in this study, two cultivars of potato were grown to different treatments of NaCl at 50 and 100 mM and SiO_2-NPs at 50 and 100 mg L-1 under in vitro and greenhouse conditions. Different growth parameters, protein analysis and antioxidant enzyme activities were examined after 35 and 90 days of treatment. Addition of NaCl to the medium induced, a significant reduction was seen in most growth traits in comparison to control and SiO_2-NPs treatments with higher NaCl concentration (100 mM) having a more serious effect on growth. At 50 mg L-1 SiO_2-NPs the deleterious effect of salinity was more pronounced than at 100 mg L-1. A protein band was marked (22.39 kDa) which can be denoted as positive marker for salt stress in cv. Sante and in cv. Proventa a novel band (70.412 kDa) corresponded to damaging activities or mechanisms as a result of toxic effects. Cultivar Proventa was less affected than cv. Sante under salt stress condition. It was concluded that application of SiO_2-NPs at 50 mg L-1 was the optimum dose to enhance and help improving in vitro plant growth and reduced the negative effects of salinity in potato.

Biswas *et al*. (2017) studied an experiment to screen salt tolerant cultivars and to compare the salinity level between indigenous and modern cultivars. In vitro selection of local and modern potato cultivars was evaluated evaluated different levels of NaCl (0, 30, 60, 90 and 120 mM). The indigenous potato Challisha and modern cultivars

Diamond and Felsina were selected and used as planting materials in this experiment. In response to different levels of NaCl significant differences were observed among the cultivars. It was reported that with the increased of the NaCl concentration plant growth and root development were gradually reduced. All three cultivars were lived well with exhibiting different growth status up to 60 mM NaCl level, but at 120 mM of NaCl they performed poorly. It was noted that Cultivar Challisha showed better performance regarding shoot length, root length, the number of nodes per plantlet and the fresh weight per plant up to 90 mM of NaCl. Thus, from the findings it was concluded that local indigenous variety Challisha was repoted as salt tolerant comparing with the modern cultivated varieties.

Khatun *et al.* (2016) performed an experiment to study the effects of salinity where four potato varieties (Diamant, Asterix, Lady Rosetta and Courage) were investigated under four different salinity levels (T_0=without salt, T_1=4 dS/m, T_2=8 dS/m, T_3=12 dS/m). Here, statistically significant variation among the different salinity levels was seen in the SPAD value of potato varieties. It was added that SPAD value decreased with increasing salinity level. Under T_0 treatment, the highest SPAD value (53.07) was measured and the minimum SPAD value (50.79) was calculated from T_3 treatment.

Gao *et al*. (2015) investigated the ultrastructural and physiological responses of potato (*Solanum tuberosum* L.) plantlets to different saline stress (0, 25, 50, 100, and 200 mM NaCl) with two consequent observations (2 and 6 weeks, respectively). From the experiment it was reported that, with the increase of external NaCl concentration and the duration of treatments, (1) the number of chloroplasts and cell intercellular spaces were seen markedly decreased, (2) even cell walls were thickened and ruptured, (3) mesophyll and chloroplasts in cells were gradually damaged to a complete disorganization containing more starch, (4) leaf Na and Cl contents increased with the decrease of K content in leaf, (5) leaf proline content and the activities of catalase (CAT) and superoxide dismutase (SOD) arisen up significantly and (6) leaf malondialdehyde (MDA) content increased significantly and stomatal area and chlorophyll content decline were also reported . Plantlet growth was inhibited by severe salt stress (200 mM NaCl). These results showed that adaptation of potato plantlets to salt stress was happened to some extent through accumulating osmoprotectants, such as proline, increasing the activities of antioxidant enzymes, such as CAT and SOD. From the findings of this experiment it was provided that ultrastructural and physiological insights into characterizing potential damages can be induced by salt stress for selecting salt-tolerant potato cultivars.

Huang *et al.* (2013) stated that accumulation of proline is an important mechanism for osmotic regulation under salt stress. In this experiment, proline accumulation profiles in roots, stems and leaves of Jerusalem artichoke (*Helianthus tuberosus* L.) plantlets under NaCl stress was evaluated. In this research, HtP5CS, HtOAT and HtPDH enzyme activities and gene expression patterns of putative HtP5CS1, HtP5CS2, HtOAT, HtPDH1, and HtPDH2 genes were examined. Jerusalem artichoke were seen to accumulate proline in roots, stems and leaves during salt stress which was a moderately salt tolerant species. Under NaCl stress condition, HtP5CS enzyme activities were increased, but in other side HtOAT and HtPDH activities generally decreased.

Jaarsma *et al.* (2013) carried out an experiment where the response of six potato cultivars to increased root NaCl concentrations was evaluated. In this study, cuttings were grown hydroponically and treated with 0mM, 60mM and 180mM NaCl for one week. Growth reduction of the cultivars Mozart and Mona Lisa under salt stress condition was strongest with a severe senescence response at 180 mM NaCl and Mozart barely survived under the treatment. The cultivars Desiree and Russett Burbank were performed as more tolerant and showed no senescence after salt treatment. Between sensitive and tolerant cultivar, a significance difference in Na^+ homeostasis was seen. It was also reported that in stem tissue, Mozart accumulated more H_2O_2 and less proline in comparison to the tolerant cultivars. The result of the analysis of the expression of proline biosynthesis genes showed a clear reduction in proline dehydrogenase (PDH) expression in both cultivars in Mozart and Desiree and an increase in pyrroline-5-carboxylate synthetase 1 (P5CS1) gene expression in Desiree, but not in Mozart.

Hayat *et al.* (2012) did an experiment where they found plants in stressful conditions accumulate an array of metabolites, particularly amino acids. Amino acids have usually been considered as precursors to and also constituents of proteins. Moreover amino acids play an important role in plant metabolism and development. Proline is an amino acid, has a beneficial role in plants when exposed to various stress conditions. Besides performing as an excellent osmolyte, proline plays three vital roles under stress condition i.e. as a metal chelator, an antioxidative defense molecule and a signaling molecule. Proline indicates that a stressful environment shows the results in its overproduction in plants and that in turn imparts stress tolerance by balancing cell turgor or osmotic balance; stabilizing membranes thereby preventing electrolyte leakage; and bringing concentrations of reactive oxygen species (ROS) within normal ranges, thus preventing oxidative burst in plants. From the reports it was indicated that enhances stress tolerance when at low concentrations, proline is supplied exogenously. However, some reports show toxic effects of proline at higher concentrations.

Das (2006) carried out an experiment to study the physio-morphological characteristics and yield potentialities of potato varieties. From this study it was found that foliage coverage (%) of Diamond was (93.3), Asterix (71.7), Granola (66.7), Quincy (90.0), Courage (63.3), Felsina (83.3), Lady Rosetta (83.3), Laura (78.3); number of tubers per hill in case of Diamond (11.7), Asterix (8.00), Granola (11.3), Quincy (9.33), Courage (7.33), Felsina (8.00), Lady Rosetta (10.3), Laura (8.33); tuber weight per hill(g) in Diamond (380), Asterix (285), Granola (275), Quincy (300), Courage (320), Felsina (333), Lady Rosetta (348), Laura (258); total dry matter (%) of Diamond was (25), Asterix (17.5), Granola (23), Quincy (31), Courage (34.5), Felsina (22.5), Lady Rosetta (22.0), Laura (27.0). According to size grade distribution of tubers the varieties Courage, Espirit, Granola, Lady rosetta, Laura were performed as superior.

Zhang *et al.* (2005) reported that for the physiological and metabolic studies of tuberization and the preliminary screenings of potential potato genotypes in vitro microtuberization provides an adequate experimental model. In this study the effects of saline stress at 0–80 mmol concentration on in vitro tuberization of two potato cultivars were investigated. The microtuberization of potato was either delayed by 5–10 days (20 and 40mmol NaCl) or inhibited completely (80 mmol NaCl) with an increase in the salt concentration, in addition to reduce in microtuber yields. Under salt stress condition two potato genotypes studied showed different trends in total soluble sugars, sucrose and starch contents of microtubers, while glucose and fructose levels showed no change. Under salt stress condition the vitamin C content in microtubers of two potato genotypes was reduced. The application of salinity from 20 to 60 mmol progressively increased proline and malondialdehyde (MDA) levels in microtubers of both the potato cultivars. These results could be beneficial and used for preliminary selections of salt tolerance in potato breeding programmes.

Shaterian *et al.* (2005) grown tetraploid potatoes (*Solanum tuberosum* L.) which are moderately salt sensitive but greater stress tolerance exists in diploid wild types. In this study stem cuttings from salt-tolerant (T) and sensitive (S) clones of early-maturing (EM) and late-maturing (LM) diploid potato clones were stressed for 5 days at the tuber initiation stage in a hydroponic sand culture under greenhouse conditions with 150 mmol NaCl. Early-maturing clones accumulated Na^+ in the leaf tissues under stress condition, but late-maturing clones generally excluded Na^+ from the leaf tissues. In the leaf tissues salt tolerant clones of both maturity types were able to tolerate high levels of Na^+. The upper leaves accumulated less Na^+ than the lower leaves in both maturity types. Proline levels increased with the increased of salt exposure but were not clearly associated with salinity tolerance. In maintenance of vegetative growth, tuber yield, and reduced leaf necrosis, tolerance was manifested. Under salt stress, salt tolerant clones of both maturity types also had less negative tuber OP than sensitive types. High yielding EMT and LMT clones either reduced tuber yield loss or even increased yield after exposure to salt stress.

Rahnama and Ebrahimzadeh (2004) conducted a research where they studied on the accumulation and metabolism of proline and its correlation with Na^+ and K^+ content in shoots and callus tissue of four potato cultivars. Four cultivars were Agria, Kennebec (relatively salt tolerant), Diamant and Ajax (relatively salt sensitive). Under salt stress Na^+ and proline contents increased in all cultivars. However, in response to NaCl treatments K^+ and protein contents reduced. In response to salt stress the activities of enzymes involved in proline metabolism, Δ1-pyrroline-5-carboxylate synthetase (P5CS) and proline dehydrogenase (ProDH) increased and decreased, respectively. The changes in the activity of P5CS and ProDH in more salt sensitive cultivars (Diamond, Ajax) were more than those in the tolerant ones. In callus tissue, for high proline accumulation, reduced growth and cell size may be partially responsible in response to high NaCl levels. Although the basic proline contents in the seedlings of more salt tolerant cultivars were higher than the sensitive ones and there was not seen any clear relationship between accumulation of proline and salt tolerance in potato.

In increasing tolerance to abiotic stress, silicon application is reported as beneficial strategies (Epstein, 2009). Silicon can increase salt tolerance by a variety of methods including reduction of Na^+ uptake, decreasing the concentration of malondialdehyde, the end product of membrane lipid peroxidation (Liang *et al.*, 2003), increasing plant water content (Romero-Aranda *et al.*, 2006), inducing antioxidant enzyme activity (Zhu *et al.*, 2004), increasing the plasma membrane H^+-ATPase activity, increasing photosynthesis activity (Liang *et al.*, 2007) and also regulating biosynthesis of compatible solutes (Zhu and Gong, 2014). Silicon can be used either as a bulk material (Guntzer *et al.*, 2012) or as a nano-particle (Tantawy *et al.*, 2015).

Potato breeding also plays an important role in improving varieties that can be cultivated under abiotic stress conditions. The selection of resistant cultivars in the field is considered important, in plant breeding program however trial fields are commonly associated with variations in salt spatial distribution, irregular moisture availability and fluctuations of temperature through the growing season. This method also includes considerable space, time, labor, equipment and planting material resources (Arvin and Donnelly, 2008).

The in vitro method of tissue culture is pointed as a powerful tool for studying many trends of development and plant growth under controlled conditions. In vitro screening for salinity tolerance has been previously evaluated (Khenifi *et al.*, 2011; Zhang and Donnelly, 1997; Potluri and Prasad, 1993).

Plants are exposed to extensive changes in their metabolism including enzymatic activities under salt stress condition (Parida and Das, 2005; Hasegawa *et al.*, 2000) changes in protein shape and function (Chen and Tabaeizadeh, 1992) and gene expression (Legay *et al.*, 2009) leading to a rise in the production of reactive oxygen species (ROS) and these ultimately leads to a reduction of growth and increase in damage to the vegetative and productive part of the plants. Plants have evolved and developed various strategies of ROS scavenging such as superoxide dismutase (SOD) and glutathione peroxidase (GPX) in response to salt stress and to reduce the effect of oxidation, and accumulation or depletion of certain metabolites can be resulted in alterations in gene expression and the levels of a small set of cellular proteins (Kamal *et al.*, 2010).

In several cases, antioxidant enzyme activity such as SOD increases in salt tolerant potato genotypes (Daneshmand *et al.*, 2010; Sajid and Aftab, 2014), however, the activity of SOD decreased with salinity stress occasionally.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

This chapter which is designed to illustrate the information concerning about the methodology in this experiment. The experiment was conducted from December 2019 to March 2020 and for salinity effects on potato varieties. This chapter describes the methodologies which is related to the location of experimental site, planting materials, design and layout of the experiment, climate and soil, pot preparation, fertilizer application, seed sowing, application of the treatment, intercultural operations, harvesting and processing, recording of data and procedures of data recording.

3.1 Experimental location

The experiment was conducted in the net house of the department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka. The location site is 23°74' N latitude and 90°35' E longitude with an elevation of 8 meter from sea level (Anonymous, 2014). The experimental site belongs to the Agro-ecological region of “Madhupur Tract” (AEZ No. 28) (Anonymous, 1988). The experimental site is shown in Appendix I.

3.2 Planting materials

For this experiment 10 varieties were used (Table 1). Eight varieties were collected from Tuber Crops Research Centre (TCRC), Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. Other two varieties were collected from Sylhet which are used as local variety.

3.3 Design and layout of the experiment

This study was executed during Rabi season in Completely Randomized Design (CRD) using two factors. In where Factor A included ten varieties of potato and Factor B included 4 different level of salinity treatments. The experiment was laid in 3 replications. In this experiment total 120 plastic pots were used.

Table 1. Name and source of ten potato varieties used in the experiment.

Sl. No.	Genotypes No.	Accession no./ Variety Name	Source of collection
01	V_1	BARI Alu-29	Tuber Crops Research Centre (TCRC), BARI
02	V_2	Pechar chokh	Sylhet
03	V_3	BARI Alu-72	Tuber Crops Research Centre (TCRC), BARI
04	V_4	Lal shila	Sylhet
05	V_5	BARI Alu-53	Tuber Crops Research Centre (TCRC), BARI
06	V_6	BARI Alu-25	Tuber Crops Research Centre (TCRC), BARI
07	V_7	BARI Alu-28	Tuber Crops Research Centre (TCRC), BARI
08	V_8	BARI Alu-36	Tuber Crops Research Centre (TCRC), BARI
09	V_9	BARI Alu-7	Tuber Crops Research Centre (TCRC), BARI
10	V_{10}	BARI Alu-73	Tuber Crops Research Centre (TCRC), BARI

BARI=Bangladesh Agricultural Research Institute

3.4 Climate and soil

Experimental location was situated in the subtropical climatic zone. Sunshine varied within experimental unit. The data of air temperature, humidity and rainfall were recorded during the time of experiment which was noted from the Bangladesh Meteorological Department, Agargaon, Dhaka (Appendix II). The mechanical and chemical properties of the soil are presented in Appendix III.

3.5 Pot preparation

For planting materials, weeds and stubbles were completely removed. Formaldehyde (45%) was applied for 48 hours to treat the soil before filling plastic pots to make it free from pathogens. Before two days of planting tubers in pots were filled up with prepared soil. Each pot was filled with 7 kg of soil. The pot size was 20 cm in height, 30 cm in top diameter and 20 cm in bottom diameter. The pot preparation was seen in plate 1.

Plate 1. Preparation of pot before sowing A. Filling the pot with soil B. Arranged the pot according to replications C. EC meter to check saline level in soil D. Checking the level of soil salinity.

3.6 Fertilizers application

Soil was well prepared and dried in the sun. According to the recommendation guide BARI (2012), the well decomposed cow dung was mixed with the soil. On an average each plastic pot was filled with soil which contained 100 g decomposed cow dung (10 tons/hectare). Total decomposed cow dung was applied before sowing the tuber to plastic pots. The recommended chemical fertilizer dose was of 350-200-220-100 kg/ha of Urea, TSP and MOP respectively. Per pot fertilizer doses were calculated according to the recommended doses of one hectare area.

3.7 Seed sowing

Total tuber size of potato is about 50-55 mm that was planted in each pot. On 15th December 2019 the potato was shown in each pot. Tuber were placed in 2-3cm depth and covered with soil in each pot properly (Plate 2A).

3.8 Application of salinity treatments

Total ten varieties were treated under four treatment of salinity (T_1: Control condition, T_2: 5 dS/m, T_3: 10 dS/m and T_4: 15 dS/m). Plants in control treatments which was denoted by T_1, were not applied salinity. But in case of others like T_2, T_3 and T_4, plants were treated with 5 dS/m, 10 dS/m and 15 dS/m salinity level respectively. To make treatment solution, salt was mixed with water and EC value was measured for the accurate application. Plants which were under control treatments (T_1) were always irrigated with fresh (non-saline) water. Saline solution was applied to T_2, T_3 and T_4 at 10 days after sowing. After that, each pot was watered as per treatment. The salinity levels in soil was adjusted by a direct reading conductivity meter (EC-meter). Application of saline water in each pot is shown in plate 2 E.


A
B
C
D

Plate 2. Different activities were done during pot experiment in net house A. Sowing of tubers B. Supervisor field visit during seedling stage of potato C. Outlook of field D. single pot plant view with levelling E. Application of salinity treatment.

3.9 Intercultural operations

Intercultural operation is needed to meet up the expected results of any growing plants (Plate 3)

3.9.1 Weeding

Weeding was performed in all pots time to time when it was required to keep plants free from weeds (Plate 3B).

3.9.2 Earthing up

To protect potatoes from light, earthing up is very important intercultural operation. Otherwise potato tubers which are developed in root area will be exposed to light become green and poisonous. Earthing up was done in 2-3week interval of growing period as per needed (Plate 3 A).

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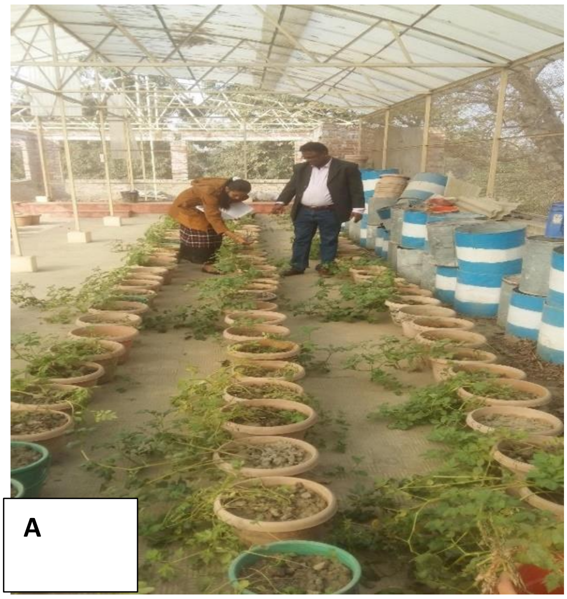

Plate 3: Intercultural operation during the time of experiment in net house A. Earthing up was done with the help of supervisor B. Supervisor was showing how to do weeding gently without harming the plant.

3.9.3 Threshing of soil sureface area

When the upper part of soil become hard threshing or cracking is done in soil of each pots thrice during the growing period.

3.9.4 Plant protection

Disease and pests are an important factor to potato production when the temperature was low. In the middle growth of potato tuber, the temperature was decreasing and for that the experimental area was infested by insects and diseases. And the late blight disease was one of them. Those diseases or infestations were effectively and timely controlled by applying recommended insecticides and fungicides in the experimental area.

3.10 Harvesting and processing

The tuber was harvested when the maximum plants showed 85-90% leaf senescence and the tops started drying up and it was after 90 days from sowing on 15 March, 2020. The total number of tubers and yield of per plant were calculated.

Tubers were collected in net bag and sun dried for the removing of moisture. During harvesting proper care was maintained to avoid any type of injuries of potatoes.

3.11 Recording of data

Data were recorded from each pot and it was based on agromorphogenic and physiological parameters. A view of the experimental site during the data collection in the net house is presented in plate 4.

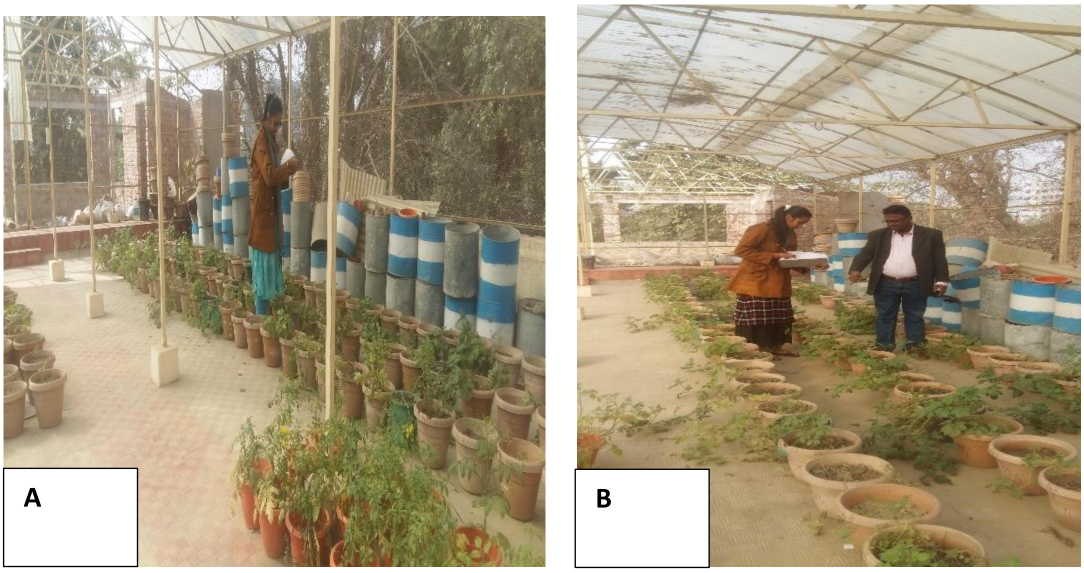

Plate 4. Recording of experimental data from the net house A. Growth data were recorded in a recorded book B. Supervisor field visit during data collection.

A. Agromorphogenic Parameters

1. Plant height (cm)
2. Number of leaflets per plant
3. Number of branches per plant
4. Dry weight of plant
5. Number of tubers per plant
6. Total Yield of tubers per plant (g)

B. Physiological Parameters

7. Chlorophyll content

8. Na^+ and K^+ content of tuber

9. Proline content

3.12 Procedures of recording data

An outline was given below about the data recording procedure during the research.

3.12.1 Plant Height (cm)

The height of each plant was recorded from each pot at the time of matured stage in centimetre scale.

3.12.2 Number of leaflets per plant

The total number of each plant leaf was recorded during the fully maturity stage of plants.

3.12.3 Number of branches per plant

Number of branches per plant was calculated from each selected plant sample during its mature stage.

3.12.4 Dry weight of plant(g)

Fruit weight was measured by electric precision balance. Average fruit weight per plant was recorded by randomly selecting five fruits per plant and mean value was calculated.

3.12.5 Number of tubers per plant

The number of tubers was calculated from plants and average number of tubers was counted.

3.12.6 Total yield of tubers per plant

After harvesting of tuber, the total number of tubers per plant was calculated and they are measured in gram(g) per plant.

Plate 5. Different types of activities during the time of harvesting of potato from the experimental pot A. Harvesting of tuber from each pot B. Collection of tuber with the instruction of supervisor C. Checking of tuber by the supervisor D.

Packing of tuber from every pot and placed in a basket. E. Total yield of some pots

3.12.7 Measuring of chlorophyll content

By using SPAD-502 plus portable chlorophyll meter, the chlorophyll content of potato plant was measured. The leaves were used to measure chlorophyll content at different salinity treatments from four different leaf in the same plant and then they were averaged for analysis. Measuring of chlorophyll content by SPAD meter is shown in Plate 6.

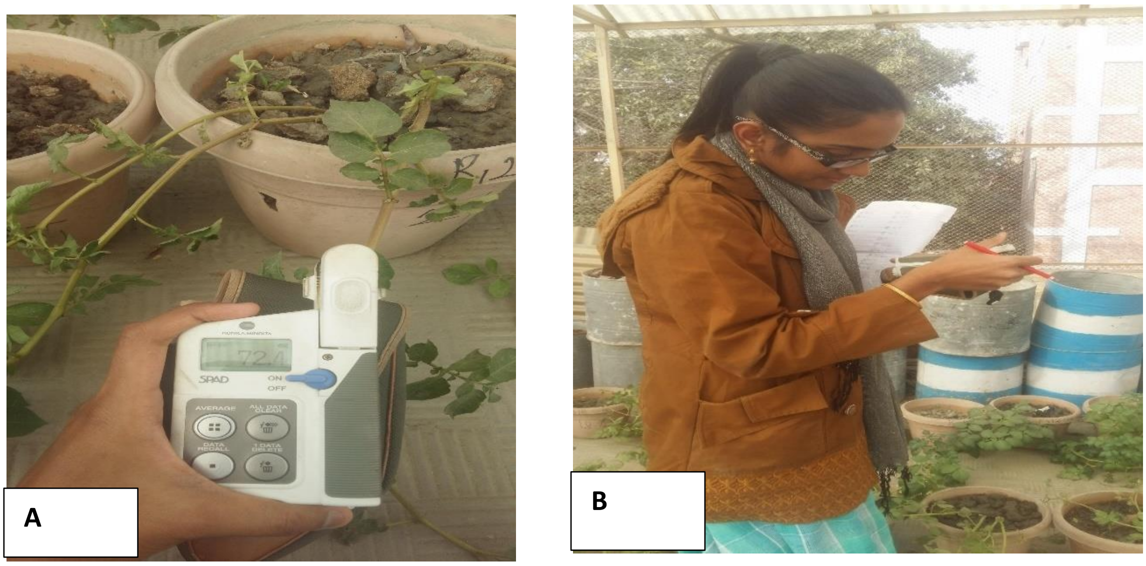

Plate 6. Different types of physiological analysis and data recording A. SPAD-502 plus portable chlorophyll meter B. Determination of chlorophyll content SPAD-502 plus portable chlorophyll meter.

3.12.8 Determination of Na^+ and K^+ Content

The potato tuber samples were oven-dried (70°C) and ground in a Wiley Hammer Mill which passed through 40 mesh screens and mixed well and stored in plastic vials. The ground tuber samples were digested by Micro-Kjeldahl method. One-gram oven-dried tuber samples were taken in kjeldahl flasks. About 15 mL of diacidic mixture (HNO_3: 60% $HClO_4$ = 2:1) were placed in a digestion tube and left to stand for 20 minutes and then transferred to digestion block. After that continued heating at 100°C, the temperature was increased gradually to 365°C to prevent frothing (50°C steps) and left to digest until yellowish colour of the solution turned to whitish colour from the heating source. Then the digestion tubes were removed and allowed to cool at room temperature. About 40 mL of de-ionized water was added to the digestion tubes carefully and the contents filtered through Whatman no. 40 filter paper into a 100 mL volumetric flask. And then filled the volume up to the mark with de-ionized water. After that the samples were stored at room temperature in labelled containers. Na^+ and K^+ content were determined by Flame Photometer.

3.12.9 Proline content in tuber

Free proline content in the tuber was determined according to the most well known method of Bates (Bates *et al*., 1973). The protocol is based on the formation of red colored by proline with ninhydrin in acidic medium and it is soluble in organic solvents like toluene. The 0.5 g tissue of potato tuber was taken and homogenized in 5 ml of 3% sulphosalycylic acid. It was taken in pre washed mortar and pestle. Then the homogenate was filtered through Whatman no.1 filter paper and collected filtrate was used for the estimation of proline content. 2 ml of extract was taken in test tube and added 2 ml of glacial acetic acid with 2 ml of ninhydrin reagent. The reaction mixture was heated in a boiling water bath at 100º C for 1 hour. Brick red colour was formed. After cooling, the formed chromophore was extracted and 4 ml of toluene was added and then transferred into a separate funnel. After this, the chromophore containing toluene was separated and its absorbance read at 520 nm in spectrophotometer. A standard curve was prepared of proline by taking 5 to 100 µg ml^{-1} concentration. Free proline content in sample was evaluated by referring to a standard curve made from known concentrations of proline by taking
following formula.

Here,

FW = fresh weight of leaf tissue

D = Initial dilution

S = absorbance at 520 nm

115.5 = Molecular weight of proline

µ moles proline/g of fresh plant material = {(mg proline/ml×ml toluene)/115.5µg/µmoles}/g sample/5

3.13 Statistical analysis

The Collected data from the experiment were analysed statistically following CRD design by MSTAT-C computer package programme to figure out the significance of the difference among the treatments. The mean value for every treatment was calculated and analysis of variance for each character was estimated. The interaction among variety and treatment was also performed. Comparison among all treatments was assessed by Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

This experiment was carried out to evaluate the stress interaction of potao varities under salinity condition based on agromorphogenic and physiological traits. In this experiment ten potato varieties were cultivated using CRD design with three replications. To screen saline tolerant variety, four treatments as T_1; control, T_2; 5 dS/m, T_3; 10 dS/m and T_4; 15 dS/m were applied. ANOVA for salinity was arranged in appendix IV. The Data are displayed and presented in tables and figures for salinity. The findings of this research have been presented and discussed under the following headlines.

4.1.1 Agromorphogenic traits

In this section agromorphogenic traits such as plant height, number of leaves per plant, number of branches per plant, number of tubers per plant, single weight of tuber per plant, yield per plant have been discussed. Data are presented in table and figures for better understanding.

4.1.1.1 Plant height (cm)

From the result of the experimen it was observed that statistically significant variation was found in plant height among ten varieties of potato (Appendix IV). The tallest plant was obtained from V_5 (45.49 cm) where shortest plant was found in V_{10} (28.29 cm) (Table 2).

The potato varieties showed significant variation to salinity treatment in terms of plant height (Appendix IV). The tallest plant was found in T_1 treatment (46.68 cm) (Table 3) and the shortest plant was found in T_4 (25.09 cm). This result showed that with the increase in salinity treatment the plant height was gradually decreased. The same result was found by Alhoshan *et al*., (2021) and Khenifi *et al*., (2011).

In case of plant height, varieties and salinity interaction showed significant variation (Appendix IV). The tallest plant was found in V_5T_1 (57.967 cm) (Table 4). In case of shortest plant, it was obtained from V_9T_4 (17.90 cm).

Table 2. Performance of potato varieties on plant height, number of leaflets per plant, number of branches per plant[Y]

Variety[X]	Plant Height (cm)	Number of leaflets per plant	Number of branches per plant
V_1	33.650 d	8.500 ef	1.833 c
V_2	29.408 f	13.750 a	1.666 cd
V_3	40.542 b	11.000 c	1.8333 c
V_4	31.058 e	13.667 a	1.5833 d
V_5	45.492 a	13.917 a	1.5833 d
V_6	40.217 b	9.583 d	2.5000 a
V_7	40.567 b	12.750 b	1.6667cd
V_8	35.592 c	10.083 d	1.750 cd
V_9	30.025 ef	8.833 e	1.750 cd
V_{10}	28.292 g	7.917 f	2.2500 b
CV	3.88	7.19	16.29
LSD(0.05)	1.12	0.642	0.243

[x] Ten potato varieties coded from V_1 to V_{10}

[Y]In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 3. Performance of salinity treatments on plant height, number of leaflets per plant, number of branches per plant[Y]

Treatment [X]	Plant Height(cm)	Number of leaflets per plant	Number of branches per plant
T_1	46.683 a	14.733 a	2.9000 a
T_2	38.790 b	11.533 b	2.1667 b
T_3	31.373 c	9.567 c	1.3000 c
T_4	25.090 d	8.167 d	1.0000 d
CV	3.88	7.19	16.29
LSD(0.05)	0.708	0.406	0.154

[X]Four salinity treatments *viz.* T_1 = Control; T_2=5 dS/m; T_3=10 dS/m; T_4=15 dS/m.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 4. Interaction effect of potato varieties and salinity treatments on plant height, number of leaflets per plant, number of branches per plant[Y]

Interaction [X]	Plant Height (cm)	Number of leaflets per plant	Number of branches per plant
V_1T_1	41.16 f	11.33 ef	3.33 b
V_1T_2	38.33 ijk	9.00 hij	2.00 e
V_1T_3	29.83 opq	7.33 klmn	1.00 f
V_1T_4	25.26 r	6.33 n	1.00 f
V_2T_1	40.66 fgh	20.00 a	2.33 de
V_2T_2	31.33 no	14.00 c	2.00 e
V_2T_3	25.50 r	11.33 ef	1.33 f
V_2 T_4	20.13 s	9.66 gh	1.00 f
V_3T_1	56.30 ab	14.33 bc	3.00 bc
V_3T_2	38.66 hijk	11.66 de	2.00 e
V_3T_3	36.03 lm	9.66 gh	1.33 f
V_3T_4	31.16 no	8.33 ijk	1.00 f
V_4T_1	38.86 ghij	19.66 a	2.33 de
V_4T_2	32.16 n	14.33 bc	2.00 e
V_4T_3	28.86 pq	11.66 de	1.00 f
V_4T_4	24.33 r	9.00 hij	1.00 f
V_5T_1	57.96 a	19.66 a	2.33 de
V_5T_2	55.23 b	14.33 bc	2.00 e
V_5T_3	38.83 ghij	11.33 ef	1.00 f
V_5T_4	29.93 nopq	10.33 fg	1.00 f
V_6T_1	50.80 c	12.66 d	4.00 a
V_6T_2	45.53 e	10.33 fg	3.00 bc
V_6T_3	36.56 klm	8.00 jkl	2.00 e
V_6T_4	27.96 q	7.33 klmn	1.00 f
V_7T_1	47.90 d	15.33 b	2.66 cd
V_7T_2	44.66 e	14.00 c	2.00 e
V_7 T_3	37.53 ijkl	12.33 de	1.00 f
V_7T_4	32.16 n	9.33 ghi	1.00 f
V_8 T_1	52.53 c	12.33 de	3.00 bc
V_8 T_2	35.26 m	10.33 fg	2.00 e
V_8 T_3	30.56 nop	9.33 ghi	1.00 f
V_8 T_4	24.00 r	8.33 ijk	1.00 f
V_9T_1	41.06 fg	11.66 de	2.66 cd
V_9T_2	36.76 jklm	9.33 ghi	2.00 e
V_9T_3	24.36 r	7.66 klm	1.33 f
V_9T_4	17.90 s	6.66 mn	1.00 f
$V_{10}T_1$	39.56 fghi	10.33 fg	3.33 b
$V_{10}T_2$	29.93 nopq	8.00 jkl	2.66 cd
$V_{10}T_3$	25.63 r	7.00 lmn	2.00 e
$V_{10}T_4$	18.03 s	6.33 n	1.00 f
CV	3.88	7.19	16.29
LSD(0.05)	2.24	1.284	0.484

[X]Ten varieties coded from V_1 to V_{10} and four salinity treatments *viz.* T_1= Control; T_2 =5 dS/m; T_3= 5 dS/m; T_4 = 15 dS/m.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.1.1.2 Number of leaflets per plant

Potato varieties showed significant variation in case of number of leaflets per plant (Appendix IV). The highest number of leaflets was found in V_5 (13.19), V_2 (13.75) and V_4 (13.66) whereas the lowest number of leaflet was observed in V_{10} (7.91) (Table 2).

The total ten varieties of potato showed significant variation in term of number of leaflets per plant under different salinity treatment (Appendix IV). The highest number of leaflets was found in T_1 (14.73) whereas the lowest leaflet number was found in T_4 (8.16) (Table 3). It was reported from the table that leaves number was decreased with the increased of salinity.

The interaction of varieties with salinity was found significant in terms of number of leaflets per plant (Appendix IV). The highest leaflet number was observed in V_2T_1 (20.00) and V_4T_1 (19.66) which was similar to V_5T_1(19.66) and the lowest number of leaflets was found in V_1T_4 (6.33) which was statistically similar with $V_{10}T_4$ (6.33) (Table 4). From this table it was figured out that in terms of number of leaflets per plant showed negative interaction with the increase of salinity level.

4.1.1.3 Number of branches per plant

The number of branches per plant was found significant among ten varieties of potato (Appendix IV). The highest number of branches per plant was found in V_6 (2.50) whereas the minimum number of branches per plant was found in V_4 (1.58) and V_5 (1.58) (Table 2).

The branches per plant of potato showed significant variation in potato varieties under salinity treatment (Appendix IV). The maximum number of branches was found in T_1 (2.90) whereas the minimum number of branches per plant was found in T_4 (1.0) (Table 3). From this table it was found that number of branches per plant was decreased with the increase of the salinity level. Alhoshan *et al.,* (2021) and Johora

(2017) found the same results in their experiments where number of branches was decreased due to increase salinity level.

The interaction of varieties with salinity was found significant variation in terms of number of branches per plant (Appendix IV). The highest number of branches per plant was found in V_6T_1 (4.00) whereas the lowest number was found in V_1T_3 (1.00) (table 4) which was similar to V_1T_4(1.0), V_2T_4(1.0), V_3T_4(1.0), V_4T_3 (1.0), V_4T_4(1.0), V_5T_3 (1.0), V_5T_4 (1.0), V_6T_4 (1.0), V_7T_3 (1.0), V_7T_4 (1.0), V_8T_3 (1.0), V_8T_4 (1.0), V_9T_4 (1.0), $V_{10}T_4$ (1.0).

4.1.1.4 Dry weight of plant (g)

Ten varieties of potato showed statistically significant variation in case of dry weight of plant (Appendix IV). The maximum dry weight (15.98 g) was found in V_2 whereas the minimum dry weight of plant (12.09) was found in V_3 (Table 5).

The dry weight of plant showed significant variation among salinity treatments (Appendix IV). The highest dry weight (19.39 g) was found in T_1 Treatment where's the lowest dry weight (9.25 g) was found in T_4 treatment (Table 6). From this table it was revealed that the dry weight of plant was reduced with the increase of salinity treatment. Johora (2017) found the same result in terms of dry weight of potato plant.

The interaction of potato varieties and salinity treatments showed non significant variation in case of dry weight of plant (Appendix IV). The highest dry weight (20.96 g) was found in V_7T_1 which is statistically similar with V_8T_1 (20.96 g) (Table 7) and the lowest dry weight (7.50 g) of potato plant was found in V_6T_4. From the table it was seen that the dry weight of plant was reduced gradually with the increase of salinity.

Table 5. Performance of potato varieties on dry weight of plant(g), number of tubers per plant, total weight of yield per plant(g) [Y]

Variety[X]	Dry weight of Plant (g)	Number of tubers per plant	Total weight of yield per Plant (g)
V_1	12.625 ef	3.8333 b	141.99 b
V_2	15.983 a	5.0000 a	50.03 f
V_3	12.092 f	4.5833 a	182.34 a
V_4	15.517 ab	4.5000 a	47.95 f
V_5	13.342 cdef	3.0833 cd	108.70 d
V_6	12.858 def	2.5833 de	80.05 e
V_7	14.175 bcd	3.0833 cd	126.25 c
V_8	14.283 bc	2.4167 e	104.47 d
V_9	13.558 cde	3.4167 bc	139.68 bc
V_{10}	13.342cdef	3.0833 cd	97.87 d
CV	12.4	19.6	15.62
LSD(0.05)	1.388	0.566	13.701

Ten potato varieties coded from V_1 to V_{10}

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 6. Performance of salinity treatments on dry weight of plant(g), number of tubers per plant, total weight of yield per plant(g) [Y]

Treatment [X]	Dry weight of Plant (g)	Number of tubers per plant	Total weight of yield per plant (g)
T_1	19.390 a	6.6333 a	201.06 a
T_2	14.800 b	3.7667 b	117.92 b
T_3	11.663 c	2.4000 c	74.98 c
T_4	9.257 d	1.4333 d	37.77 d
CV	12.4	19.6	15.62
LSD(0.05)	0.877	0.358	8.665

[X]Four salinity treatments *viz.* T_1= Control; T_2= 5 dS/m; T_3= 10 dS/m; T_4= 15 dS/m.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 7. Interaction effect of potato varieties and salinity treatments on dry weight of plant, number of tubers per plant, total weight of yield per plant[Y]

Interaction [X]	Dry weight of Plant (g)	Number of tubers per plant	Total weight of yield per Plant (g)
V_1T_1	18.16 bcd	6.66 b	245.00 bc
V_1T_2	14.06 ghijk	4.33 efgh	156.67 fg
V_1T_3	9.80 mnopqr	2.66 jklm	102.33 hijkl
V_1T_4	8.46 qr	1.66 mno	63.97 mnop
V_2T_1	20.53 abc	9.66 a	103.07 hijk
V_2T_2	17.50 def	4.66 defg	47.97 opqr
V_2T_3	14.26 ghijk	3.33 hijk	33.47 qrst
$V_2 T_4$	11.63jklmnop	2.33 klmn	15.63 st
V_3T_1	17.96 cd	6.66 b	270.83 ab
V_3T_2	12.16 ijklm	5.33 cde	202.40 de
V_3T_3	9.80 mnopqr	4.00 fghi	166.00 fg
V_3T_4	8.43 qr	2.33 klmn	90.13 ijklm
V_4T_1	20.93 ab	9.33 a	111.33 hi
V_4T_2	16.73 defg	4.33 efgh	43.67 pqr
V_4T_3	13.30 hijkl	3.00 ijkl	27.40 rst
V_4T_4	11.10 lmnopq	1.33 no	9.40 t
V_5T_1	17.73 de	5.66 bcd	179.00 ef
V_5T_2	14.90 fghi	3.00 ijkl	118.33 h
V_5T_3	11.76 jklmno	2.33klmn	88.80 ijklm
V_5T_4	8.96 pqr	1.33no	48.67 opqr
V_6T_1	19.50 abcd	5.00def	158.63 fg
V_6T_2	14.40 ghij	2.66 jklm	78.77 jklmn
V_6T_3	10.03mnopqr	1.66 mno	58.53 nopq
V_6T_4	7.500 r	1.00 o	24.27 rst
V_7T_1	20.967 a	6.33 bc	261.33 ab
V_7T_2	15.06 efgh	3.33 hijk	151.00 g
$V_7 T_3$	11.50 klmnop	1.66 mno	64.60 mnop
V_7T_4	9.16 nopqr	1.00 o	28.07 rst
$V_8 T_1$	20.96 a	4.66 defg	227.17 cd
$V_8 T_2$	14.40 ghij	2.66 jklm	105.37 hij
$V_8 T_3$	11.90 jklmn	1.33 no	56.87 nopq
$V_8 T_4$	9.86 mnopqr	1.00 o	28.50 rst
V_9T_1	19.03 abcd	6.66 b	277.73 a
V_9T_2	15.03 efgh	3.66 ghij	162.03 fg
V_9T_3	11.83 jklmno	2.00 lmno	76.73 klmn
V_9T_4	8.33 qr	1.33 no	42.20 pqrs
$V_{10}T_1$	18.10 cd	5.66 bcd	176.53 efg
$V_{10}T_2$	13.73 hijkl	3.66 ghij	113.00 hi
$V_{10}T_3$	12.43 hijklm	2.00 lmno	75.10 lmno
$V_{10}T_4$	9.10 opqr	1.00 o	26.83 rst
CV	12.4	19.6	15.62
LSD(0.05)	2.776	1.133	27.402

[X]Ten varieties coded from V_1 to V_{10} and four salinity treatments *viz.* T_1 = Control; T_2 = 5 dS/m; T_3 = 10 dS/m; T_4 = 15 dS/m.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.1.1.5 Number of tubers per plant

Different salinity levels had significant effect on the number of tubers per plant (Appendix IV). The total number of tubers per plant gradually decreased with the increase of the salinity level. The maximum number of tubers per plant was found in V_2 (5.0), V_3 (4.58), V_4 (4.50) whereas the minimum number of tubers per plant (2.41) was found in V_8 (table 5).

The number of tubers per plant showed significant differences when different levels of salinity treatments were applied (Appendix IV). The maximum number of tubers (6.63) was obtained in T_1 treatment (Table 6) while the minimum number of tubers per plant (1.43) was found in T_4 treatment. From the result it was revealed that number of tubers per plant decreased with the increase of salinity level.

The number of tubers per plant was affected significantly by the interaction among the potato varieties and salinity level (Appendix IV). The highest number of tubers per plant was found in V_2T_1 (9.66) and V_4T_1 (9.33) whereas V_6T_4 (1.0) produced the minimum number of tubers per plant which are statistically similar with V_7T_4 (1.00), V_8T_4 (1.00), $V_{10}T_4$ (1.0) (Table 7).

4.1.1.6 Total yield of tubers per plant (g)

Ten potato varieties showed statistically significant variation in terms of yield per plant (Appendix IV). The highest yield (182.34 g/Plant) was found in V_3 whereas the lowest yield was obtained from V_2 (50.03g per plant) and V_4(47.95 g per plant) (Table 5). The total yield per plant showed statistically significant variation among different salinity treatments (Appendix IV). The highest yield (201.06 g per plant) was found in T_1 treatment whereas the lowest yield (37.77g per plant) was found in T_4 treatment (Table 6). Zohora (2017) and Ghosh *et al.,* (2001) found the same result in terms of yield of potato under salinity stress condition. From the result it was found that yield per plant was decreased with the increase of salinity level. The total yield reduced with the increase of salinity due to the reduction of number of leaves per plant, number of tuber per plant with the increase of salinity.

The interaction among varieties and salinity level showed statistically significant variation in terms of yield per plant (Appendix IV). The lowest yield per plant was found in V_4T_4 (9.40 g) whereas the highest yield per plant (277.73 g) was found in V_9T_1 (Table 7). The salinity level decreased the total and marketable tuber yield due to the decrease in the total number of tubers per plant and average tuber weight.

4.1.2 Physiological traits

Varieties stress interaction was evaluated based on some physiological traits like Chlorophyll content, Na^+ content, K^+ content and proline content. ANOVA is displayed in Appendix IV and data are presented in table and graph.

4.1.2.1 Chlorophyll content

Ten varieties showed statistically significant variation in terms of chlorophyll content (Appendix IV). The highest chlorophyll content (63.89%) was found in V_8 whereas the minimum chlorophyll content (32.75 %) was found in V_6 (Appendix V). The graphical presentation of the effect of varieties on chlorophyll content was seen in Figure 1.

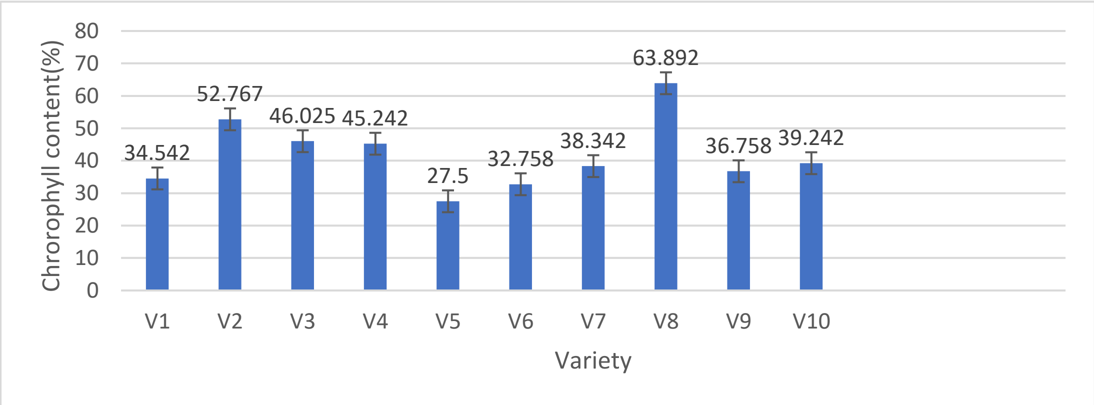

Figure 1. Effect of potato varieties on chlorophyll content

Chlorophyll content showed statistically significant variation among the treatments (Appendix IV). The maximum chlorophyll content (58.76 %) was found in T_1 treatment whereas the lowest chlorophyll content (26.53 %) was found in T_4 salinity treatments (Appendix VI).

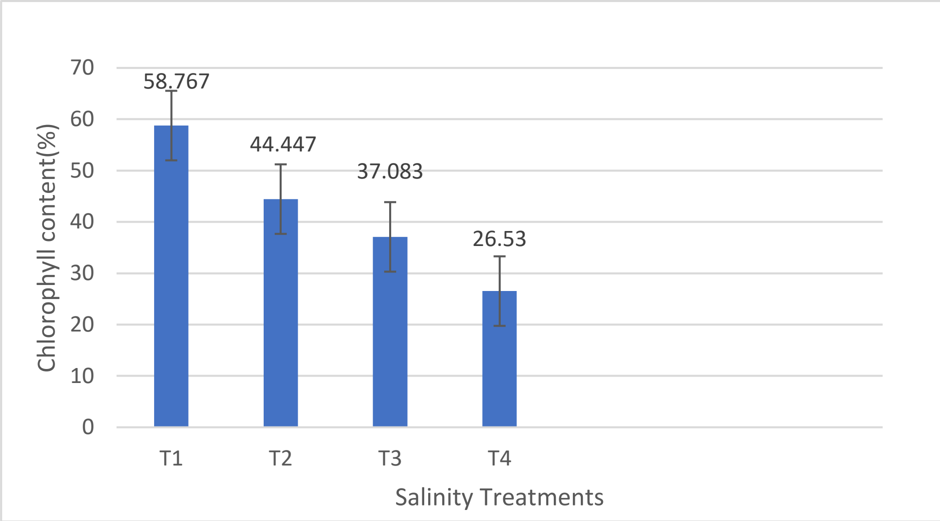

Figure 2. Effect of salinity treatments on chlorophyll content

From the Figure 2 it was showed that chlorophyll content decreased with the increase of salinity treatments. Zohora (2017) and Munira *et al.*, (2015) found the same same result where they observed that chlorophyll content was reduced with the increase of salinity level. Heidari (2012) reported that chlorophyll content in leaves was influenced by salinity stress and this effect depends on the levels of salinity.

Chlorophyll content showed statistically significant variation among the interactions of varieties and salinity treatment (Appendix IV). The highest Chlorophyll content (83.46%) was found in V_8T_1 combination and in another side the lowest chlorophyll content (10.60 %) was found in V_5T_4 combination (Appendix VII). The Figure 3 showing the graphical presentation of the interaction effect of varieties and chlorophyll content of potato.

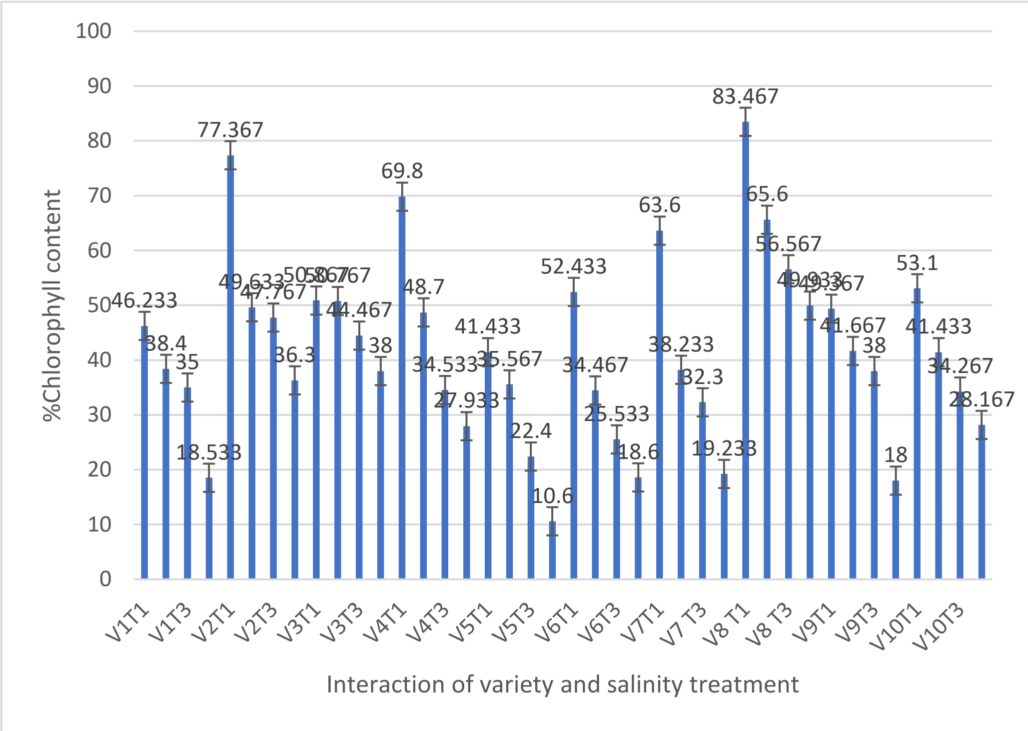

Figure 3. Interaction effect of potato varieties and different level of salinity treatments on chlorophyll content

4.1.2.2 Na^+ content (%)

Statistically significant variation was found in ten varieties of potato tuber in term of Na^+ content (Appendix IV). The lowest Na^+ content (0.11 %) was found in V_2 Variety in where the highest Na^+ content (0.20%) was found in V_7 (Appendix V). In the figure 4 it has been shown the effect of potato varieties on Na^+ content.

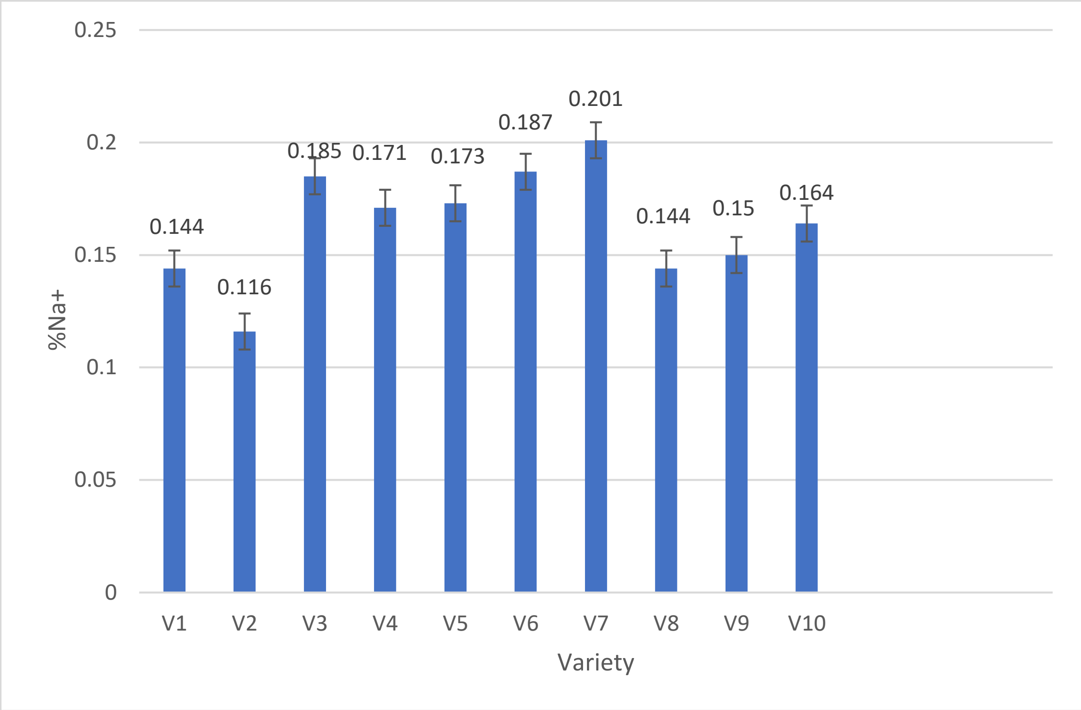

Figure 4. Effect of potato varieties on Na^+ content

The value of Na^+ content showed statistically significant variation under salinity treatments (Appendix IV). The highest value of Na^+ content (0.26%) was found in T_4 treatment while The lowest value of Na^+ (0.03 %) was observed under T_1 salinity treatment (Appendix VI). The effect of salinity treatments on Na^+ content has been shown in graphical diagram in figure 5. It was noted that with the increase of salinity, Na^+ content was also increased. Zohora (2017) and Khatun *et at.*, (2016) also reported the same thing that the value of Na^+ content was increased with increase of salinity level in their experiment.

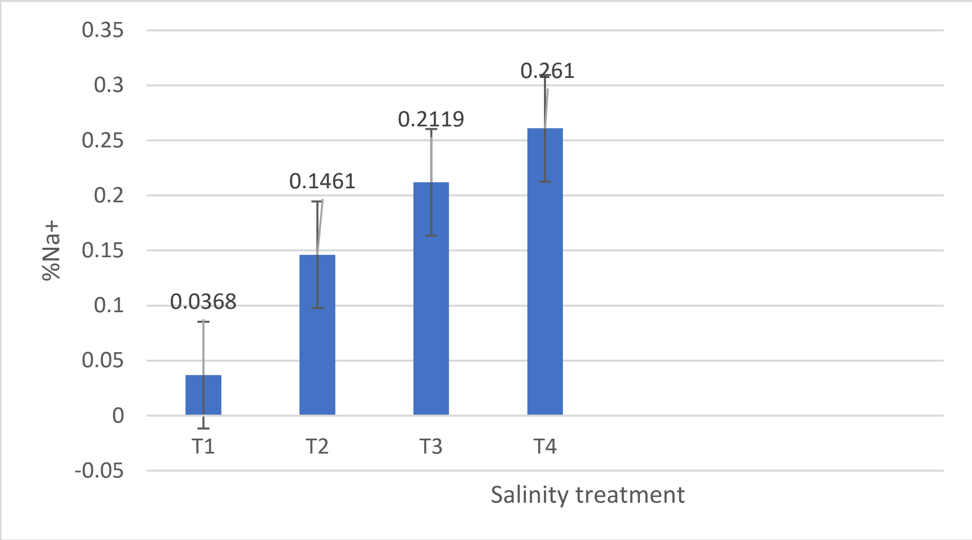

Figure 5. Effect of salinity treatments on Na^+ content

The interaction among salinity treatments and varieties showed statistically significant variation in terms of Na^+ content in tuber (Appendix IV). The highest value

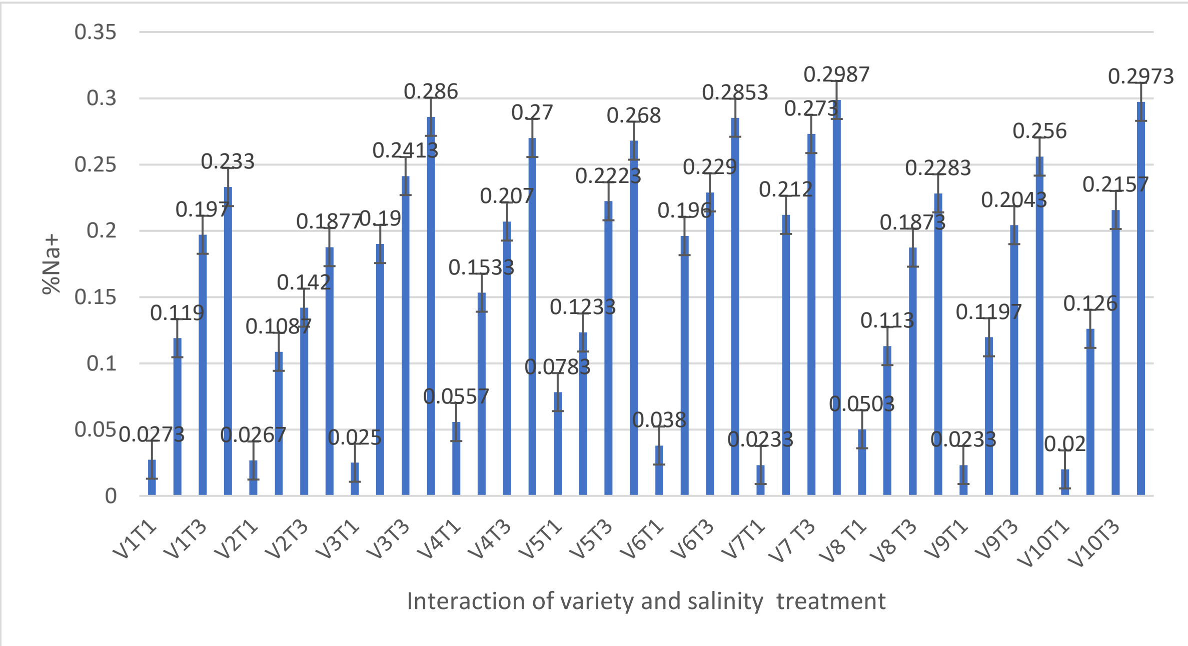

Figure 6. Interaction effect of potato varieties and different level of salinity treatments on Na^+ content

of Na^+ content (0.29 %) was found in V_7T_4 which was statistically similar with $V_{10}T_4$ (0.29 %) whereas the lowest value of Na^+ content (1.07 %) was reported in V_1T_1 (0.02), which was statistically similar with V_2T_1 (0.02%), V_3T_1 (0.02%), V_7T_1 (0.02%), V_9T_1 (0.02%), $V_{10}T_1$ (0.02%) (Appendix VII). There has a graphical presentation (Figure 6) which displays the interaction effect of varieties and salinity treatments on Na^+ content of potato

4.1.2.3 K^+ content (%)

The value of K^+ content showed statistically non-significant variation among ten potato varieties (Appendix IV). The highest value of K^+ content (0.20 %) was reported in V_4 whereas the lowest value of K^+ content (0.08 %) was found in V_5 variety (Appendix V). The effect of varieties on K^+ content of potato is showed in Figure 7.

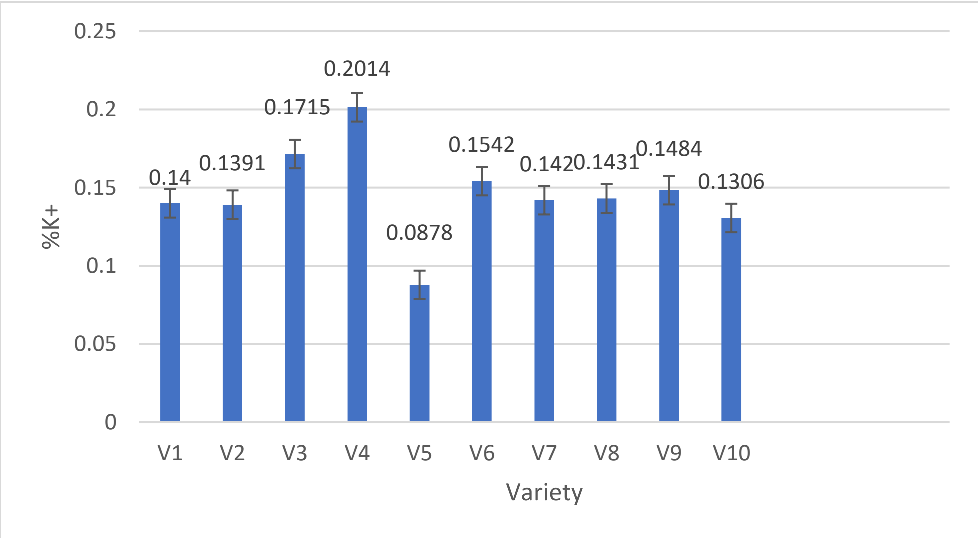

Figure 7. Effect of potato varieties on K^+ content

K^+ content showed statistically significant variation under different salinity treatment (Appendix IV). The highest value of K^+ (0.20 %) was reported in T_1 and the lowest value of K^+ content (0.05%) was found in T_4 treatment (Appendix VI). The effect of salinity on K^+ content is presented on figure 8. K^+ content was decreased with the increase of salinity treatments. This statement was supported by Zohora (2017) and khatun *at al*. (2016). Due to increase the Na^+ content around the root zone, K^+ uptake is reduced (Shabani *et al*., 2012).

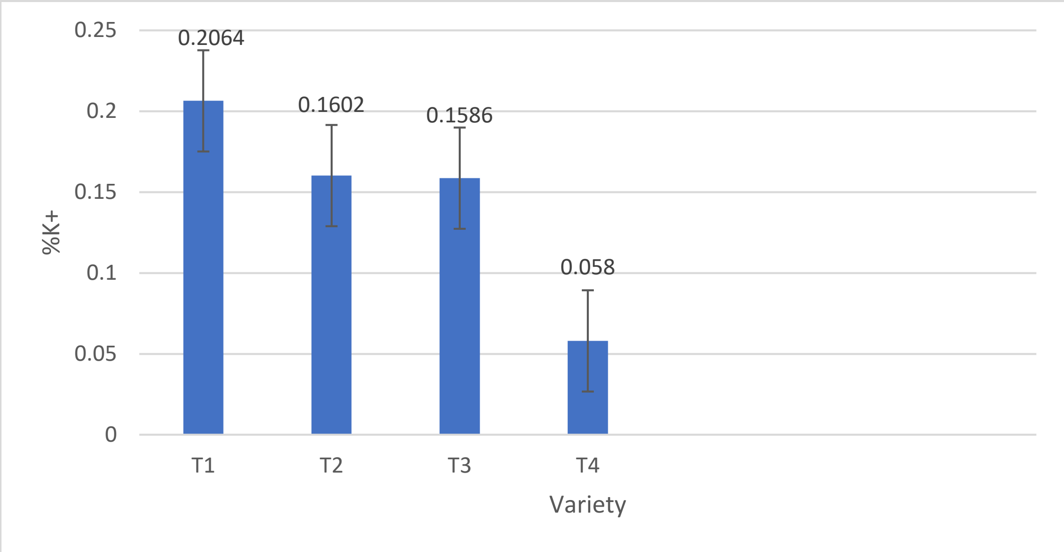

Figure 8. Effect of salinity treatments on K^+ content

The value of K^+ content showed statistically non-significant result among the interaction of potato varieties and salinity treatment (Appendix IV). The highest value of K^+ content (0.40%) was found in V_4T_3 whereas the lowest value of K^+ content

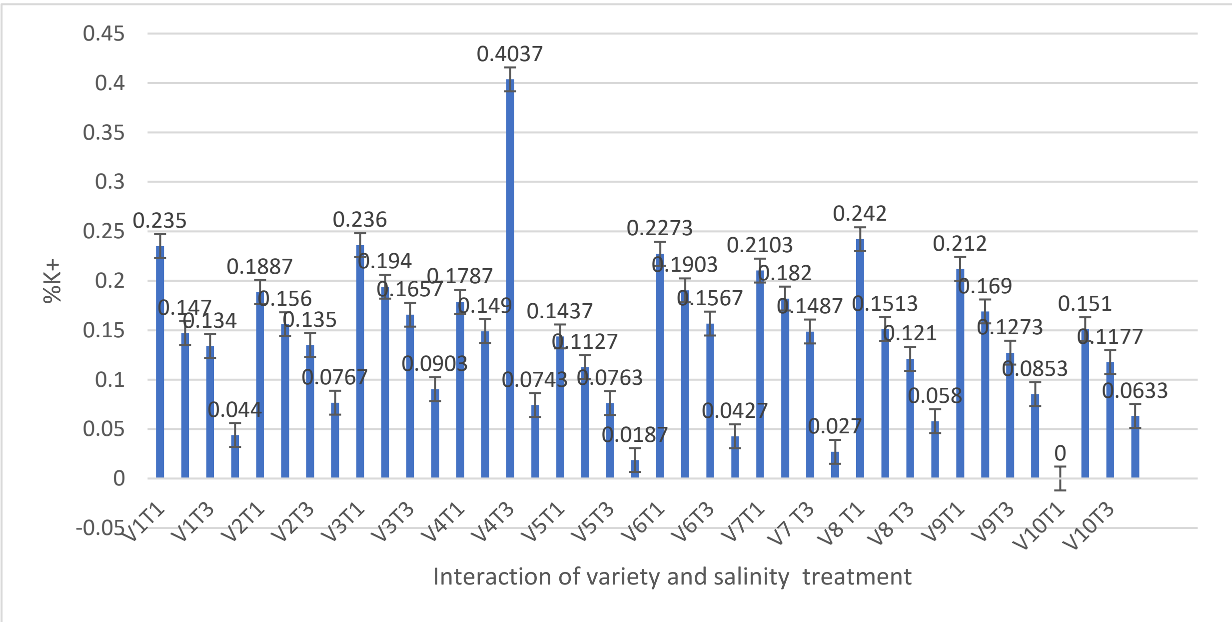

Figure 9. Interaction effect of potato varieties and different level of salinity treatments on K^+ content

(0.01%) was reported in V_5T_4 combination (Appendix VII). The graphical presentation (Figure 9) shows the interaction effect of varieties and salinity treatments on K^+ content of potato.

4.2.2.4 Proline content (μmol^{-1}FW)

Proline content showed statistically significant variation in ten potato varieties (Appendix IV). The highest proline content was reported in V_7 (14.02 μmol^{-1}FW) which was similar to V_3 (13.76 μmol^{-1}FW) whereas the lowest value of proline content was found in V_9 (10.68 μmol^{-1}FW) (Appendix V). The figure 10 shows the graphical presentation of the effect of varieties on proline content of potato tuber.

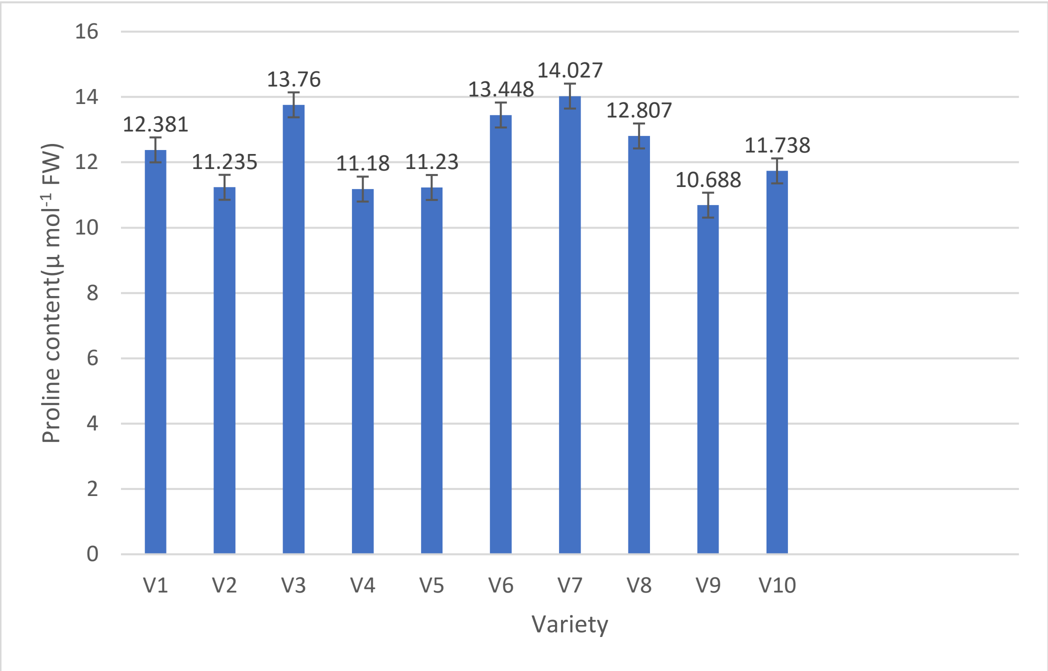

Figure 10. Effect of potato varieties on proline content of potato tuber

Proline content showed statistically significant variation among the salinity treatments (Appendix IV). The highest value of proline content was obtained from T_4 (21.63μ mol^{-1}FW) whereas the lowest value of proline content was found in T_1 (0.49μmol^{-1} FW) (Appendix VI). With the increase of salinity stress, proline content was increased (Figure 11). Zohora (2017) and Im *et al.* (2016) also reported the same result that the proline content was increased with the increase of salinity treatment.

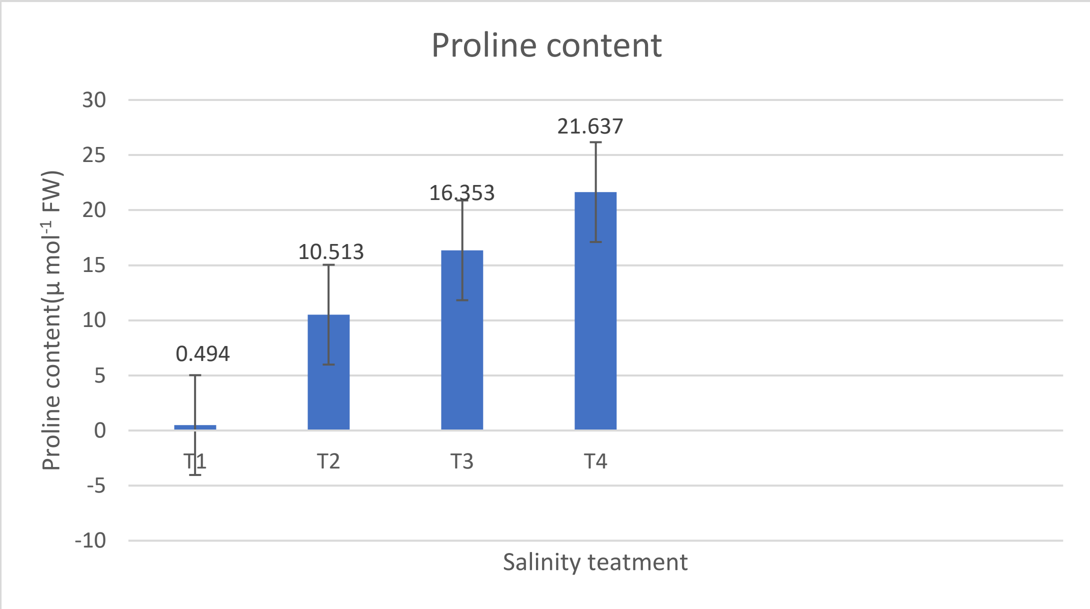

Figure 11. Effect of salinity treatments on proline content of potato tuber

Proline content showed statistically significant result among the interaction of variety and salinity treatments (Appendix IV).

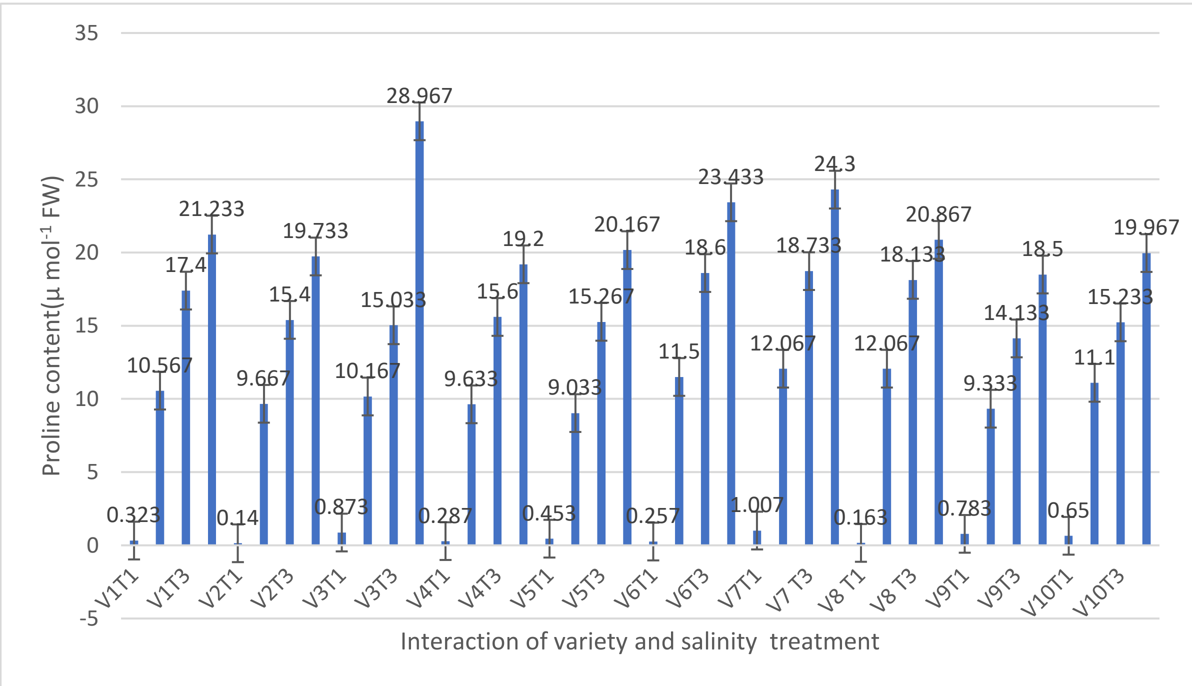

Figure 12. Interaction effect of potato varieties and different level of salinity treatments on proline content of potato tuber

The highest proline content was found in V_3T_4 (28.96 μmol^{-1}FW) whereas the lowest proline content was found in V_1T_1 (0.3 μmol^{-1}FW), V_2T_1 (0.1 μmol^{-1}FW), V_3T_1 (0.8 μmol^{-1}FW), V_4T_1(0.2 μmol^{-1}FW), V_5T_1(0.4 μmol^{-1}FW), V_6T_1 (0.2 μmol^{-1}FW), V_7T_1 (1.0 μmol^{-1}FW), V_8T_1 (0.16 μmol^{-1}FW), V_9T_1 (0.7 μmol^{-1}FW), $V_{10}T_1$ (0.6 μmol^{-1}FW) (Appendix VII). The interaction effect of varieties and salinity treatments on proline content of potato tuber is showed in Figure 12.

CHAPTER V

SUMMARY AND CONCLUSION

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SUMMARY AND CONCLUSION

The experiment was conducted for salinity in net house, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka from December 2019 to March 2020 to screen potato variety against salinity stress. This experiment was held with ten potato varieties and the treatments consisted of four different levels of salinity viz, T_1 (control), T_2 (5 dS/m), T_3 (10 dS/m) and T_4 (15 dS/m) with CRD design with three replications. Varieties and salinity stress interaction were estimated based on agromorphogenic and physiological traits. Data were analysed statistically. ANOVA, varieties performance, stress effect, variety stress interaction were arranged in different tables and graphs.

In this experiment significant variation and in some cases non-significant variation were found under different treatments in all the parameters where potato plant was treated with sodium chloride (NaCl) contamination by adding salt water into the soil. Plants grown on normal soil (control treatment) showed the positive response of potato varieties.

In interaction of potato varieties with salinity treatment, significant variation was found in case of plant height. The tallest plant was obtained from V_5T_1 (57.967 cm) whereas the shortest plant was found in V_9T_4 (17.90 cm) and this result was statistically similar to $V_{10}T_4$ (18.03) and V_2T_4 (20.13). In terms of leaflet number, varieties with salinity interaction showed statistically significant variation. The maximum leaflet number was observed in V_2T_1 (20.00) and V_4T_1 (19.66) which was similar to V_5T_1(19.66) and the minimum leaflet number was found in V_1T_4 (6.33) which was also statistically similar with $V_{10}T_4$ (6.33). The interaction of varieties with salinity treatment was found statistically significant in terms of number of branches per plant. The highest number of branches per plant was found in V_6T_1 (4.00) and in other side the lowest number was found in V_1T_3 (1.00) which was statistically similar to V_1T_4(1.0), V_2T_4(1.0), V_3T_4(1.0), V_4T_3 (1.0), V_4T_4(1.0), V_5T_3 (1.0), V_5T_4 (1.0), V_6T_4 (1.0), V_7T_3 (1.0), V_7T_4 (1.0), V_8T_3 (1.0), V_8T_4 (1.0), V_9T_4 (1.0), $V_{10}T_4$ (1.0). The value of dry weight of potato plant showed statistically non-significant variation result in the interaction of potato varieties with salinity treatment. The highest dry weight of potato plant was found in V_7T_1 (20.96 g) which was statistically similar with V_8T_1 (20.96 g) and the lowest dry weight (7.50 g) of potato plant was found in V_6T_4. In case of number of tubers per plant highest number was found in V_2T_1 (9.66) and V_4T_1 (9.33) whereas V_6T_4 (1.0) produced lowest number of tubers per plant which was statistically similar with V_7T_4 (1.00), V_8T_4 (1.00), $V_{10}T_4$ (1.0). In terms of yield, the interaction among varieties and salinity level showed statistically significant variation. The minimum yield per plant was found in V_4T_4 (9.40 g) whereas the maximum yield per plant (277.73 g) was found in V_9T_1.

The interaction effect of varieties with salinity treatment on chlorophyll content showed statistically significant variation. The highest chlorophyll content was found in V_8T_1 (83.46%) combination whereas the lowest chlorophyll content (10.60 %) was found in V_5T_4 combination. In terms of Na^+ content in tuber the interaction of varieties with salinity treatment showed statistically significant variation. The maximum value of Na^+ content (0.29 %) was found in V_7T_4 which was statistically similar with $V_{10}T_4$ (0.29 %) whereas the minimum value of Na^+ content (1.07 %) was found in V_1T_1 (0.02), which was statistically similar with V_2T_1 (0.02%), V_3T_1 (0.02%), V_7T_1 (0.02%), V_9T_1 (0.02%), $V_{10}T_1$ (0.02%). The value of K^+ content showed statistically non-significant variation result in the interaction of potato varieties with salinity treatment. The maximum value of K^+ content was found in V_4T_3 (0.40%) whereas the lowest value of K^+ content (0.01%) was reported in V_5T_4 combination. In terms of proline content, the interaction effects of variety with salinity treatments showed statistically significant result. The highest proline content was observed in V_3T_4 (28.96 μ mol^{-1} FW) whereas the lowest proline content was found in V_1T_1 (0.3 μmol^{-1}FW), V_2T_1 (0.1 μmol^{-1}FW), V_3T_1 (0.8 μmol^{-1}FW), V_4T_1 (0.2 μmol^{-1}FW), V_5T_1 (0.4 μmol^{-1}FW), V_6T_1 (0.2 μmol^{-1}FW), V_7T_1 (1.0 μmol^{-1}FW), V_8T_1 (0.16 μmol^{-1}FW), V_9T_1 (0.7 μmol^{-1}FW), $V_{10}T_1$ (0.6 μmol^{-1} FW).

From the result of this experiment, it has been concluded that V_3 performed well under T_2 and T_3 treatment because higher number of tuber and yield were obtained from it. The variety V_9 also given second highest yield under T_2 treatment. So V_3 variety is already recommended for mild to moderate saline prone area in Bangladesh. However, to attain a final decision more research work on potato with the same treatment should be done in different saline prone area.

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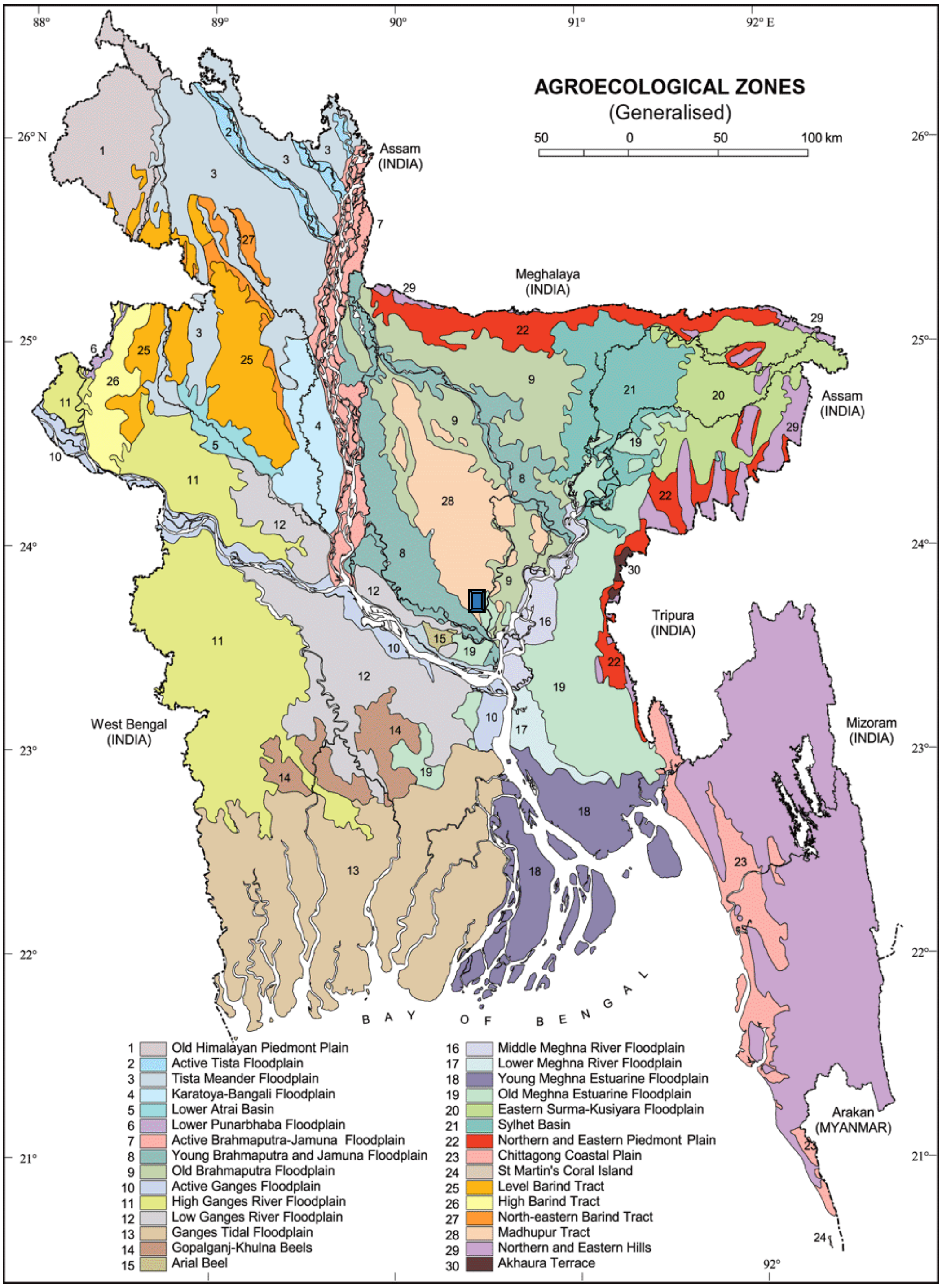
APPENDICES

Appendix I. Map showing the experimental site under the study.



The experimental site under the study

Appendix II. Monthly records of dry bulb temperature, relative humidity, rainfall and sea level pressure during the period from November 2019 to April 2020.

Month	Year	Monthly average dry-bulb temperature (^{o} C)	Monthly average relative humidity (%)	Monthly average rainfall (mm)	Monthly average sea level pressure in milliber
November	2019	24.9	74	37	1011.5
December	2019	19.3	74	5	1015.2
January	2020	18.5	76	21	1014.7
February	2020	21.6.	59	1	1014.5
March	2020	26.4	57	30	1010.7
April	2020	27.9	72	127	1008.9

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka.

Appendix III. The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation

A. Mechanical composition of the soil

Particle size	constitution
Sand	40%
Silt	40%
Clay	20%
Texture	Loamy

B. Chemical composition of the soil:

Soil characters	**Value**
Organic matter	1.44 %
Potassium	0.15 meq/100 g soil
Calcium	3.60 meq/100 g soil
Magnesium	1.00 meq/100 g soil
Total nitrogen	0.072
Phosphorus	22.08 µg/g soil
Sulphur	25.98 µg/g soil
Boron	0.48 µg/g soil
Copper	3.54 µg/g soil
Iron	262.6 µg/g soil
Manganese	164 µg/g soil
Zinc	3.32 µg/g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka

Appendix IV. Analysis of variance of the data on agromorphogenic and physiological traits under salinity treatments

Source	Df	Mean sum of square									
		Plant Height(cm)	No. of leaflet	No. of Branch	%Chlorophyll content	Dry weight of Plant(gm)	No. of Tuber/plant	Total weight of yield /Plant(gm)	%Na+	%K+	Proline content
Replication	2	11.68	18.30	0.16	123.29	4.99	2.03	884.00	0.001	0.006	9.62
Variety (A)	9	420.49**	66.06**	1.08**	1361.02**	18.33**	9.39**	21175.00**	0.008**	0.010^{ns}	17.49**
treatment (B)	3	2612.88**	243.04**	22.28**	5502.58**	574.53**	153.56**	147820.00**	0.282**	0.117**	2461.74**
A X B	27	31.18**	4.26**	0.23**	80.79**	1.82^{ns}	1.42**	1897.00**	0.002**	0.007^{ns}	8.27**
Error	78	1.90	0.63	0.09	8.88	2.92	0.49	284.00	0.00013	0.007	0.68

*Significant at 0.05 level ofprobability, **Signifact at 0.01 level of probability and ns = non-significant.

Appendix V. Effect of varieties on physiological parameters of potato varieties

Variety[X]	%Chlorophyll content	%Na^+	%K^+	Proline content
V_1	34.542 gf	0.1441 d	0.1400 abc	12.381 cd
V_2	52.767 b	0.1163 e	0.1391 abc	11.235 ef
V_3	46.025 c	0.1856 b	0.1715 ab	13.760 a
V_4	45.242 c	0.1715 c	0.2014 a	11.180 ef
V_5	27.500 h	0.1730 c	0.0878 c	11.230 ef
V_6	32.758 g	0.1871 b	0.1542 ab	13.448 ab
V_7	38.342 de	0.2017 a	0.1420 abc	14.027 a
V_8	63.892 a	0.1448 d	0.1431 abc	12.807 bc
V_9	36.758 ef	0.1508 d	0.1484 abc	10.688 f
V_{10}	39.242 d	0.1648 c	0.1306 bc	11.738 de
CV	7.15	7.06	5.5	6.72
LSD(0.05)	2.422	0.009	0.065	0.668

Appendix VI. Effect of salinity treatments on physiological parameters of potato varieties

Treatment x	%Chlorophyll content	%Na^+	%K^+	Proline content
T_1	58.767 a	0.0368 d	0.2064 a	0.494 d
T_2	44.447 b	0.1461 c	0.1602 b	10.513 c
T_3	37.083 c	0.2119 b	0.1586 b	16.353 b
T_4	26.530 d	0.2610 a	0.0580 c	21.637 a
CV	7.15	7.06	5.5	6.72
LSD(0.05)	1.531	0.005	0.041	0.422

APPENDIX VII. Effect of interaction between variety and level of salinity treatments on pysiological parameters of potato

Interaction [X]	%Chlorophyll content	%Na^+	%K^+	Proline content
V_1T_1	46.233 hij	0.027 r	0.235 b	0.323 p
V_1T_2	38.400 kl	0.119 o	0.147 bcdefgh	10.567 mn
V_1T_3	35.000 lm	0.197 ijkl	0.134 bcdefgh	17.400 i
V_1T_4	18.533 q	0.233 ef	0.044 fgh	21.233 c
V_2T_1	77.367 b	0.026 r	0.188 bcde	0.140 p
V_2T_2	49.633 fgh	0.108 o	0.156 bcdefg	9.667 no
V_2T_3	47.767 ghi	0.142 mn	0.135 bcdefgh	15.400 jk
$V_2 T_4$	36.300 lm	0.187 l	0.076 defgh	19.733 defg
V_3T_1	50.867 fgh	0.025 r	0.236 b	0.873 p
V_3T_2	50.767 fgh	0.190 kl	0.194 bcd	10.167 mno
V_3T_3	44.467 ij	0.241 de	0.165 bcdef	15.033 jk
V_3T_4	38.000 kl	0.286 ab	0.090 cdefgh	28.967 a
V_4T_1	69.800 c	0.055 q	0.178 bcde	0.287 p
V_4T_2	48.700 fghi	0.153 m	0.149 bcdefgh	9.633 no
V_4T_3	34.533 lm	0.207 hijk	0.403 a	15.600 j
V_4T_4	27.933 no	0.270 bc	0.074 defgh	19.200 efgh
V_5T_1	41.433 jk	0.078 p	0.143 bcdefgh	0.453 p
V_5T_2	35.567 lm	0.123 no	0.112 bcdefgh	9.033 o
V_5T_3	22.400 pq	0.222 fgh	0.076 defgh	15.267 jk
V_5T_4	10.600 r	0.268 bc	0.018 h	20.167 cde
V_6T_1	52.433 efg	0.038 qr	0.227 b	0.257 p
V_6T_2	34.467 lm	0.196 jkl	0.190 bcd	11.500 lm
V_6T_3	25.533 op	0.229 efg	0.156 bcdefg	18.600 ghi
V_6T_4	18.600 q	0.285 ab	0.042 fgh	23.433 b
V_7T_1	63.600 d	0.023 r	0.210 bc	1.007 p
V_7T_2	38.233 kl	0.212 ghij	0.182 bcde	12.067 l
$V_7 T_3$	32.300 mn	0.273 bc	0.148 bcdefgh	18.733 fghi
V_7T_4	19.233 q	0.298 a	0.027 gh	24.300 b
$V_8 T_1$	83.467 a	0.050 q	0.242 b	0.163 p
$V_8 T_2$	65.600 cd	0.113 o	0.151 bcdefg	12.067 l
$V_8 T_3$	56.567 e	0.187 l	0.121 bcdefgh	18.133 hi
$V_8 T_4$	49.933 fgh	0.228 efg	0.058 efgh	20.867 cd
V_9T_1	49.367 fgh	0.023 r	0.212 bc	0.783 p
V_9T_2	41.667 jk	0.119 o	0.169 bcdef	9.333 no
V_9T_3	38.000 kl	0.204 hijkl	0.127 bcdefgh	14.133 k
V_9T_4	18.000 q	0.256 cd	0.085 cdefgh	18.500 ghi
$V_{10}T_1$	53.100 ef	0.020 r	0.190 bcd	0.650 p
$V_{10}T_2$	41.433 jk	0.126 no	0.151 bcdefg	11.100 lm
$V_{10}T_3$	34.267 lm	0.215 fghi	0.117 bcdefgh	15.233 jk
$V_{10}T_4$	28.167 no	0.297 a	0.063 defgh	19.967 cdef
CV	7.15	7.06	5.5	6.72
LSD(0.05)	4.844	0.018	0.131	1.337